STUDENT'S HEALTH

THE ART OF WELLBEING

inspired from nature to prmote good health and happiness

Master Thesis

Wellbeing indicators

The relationship between campus settings and student's health

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Polytechnic University of Turin, Department of Architecture and Design, Fall 2019

Development and Assessment of Wellbeing indicators of an Educational Building

Master Research Thesis

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Abstract

This thesis aims at selecting the primary wellbeing indicators which significantly affect the health of students. To this end, various criteria and indicators of three campus assessment tools namely Green Metric, Star and International Well Building Standard (IWBS) are compared. Focusing on occupants' health, IWBS protocol is chosen to apply to a classroom at Polytechnic University of Turin (Polito) in Italy. Considering experts' opinions and the data availability, seven indicators are selected among the existing 105 features in IWBS. These seven indicators are categorized into two areas of indoor air and light, that represent different effects on the student's health. Verifying the data of these indicators according to the target of IWBS, it is found that only five indicators meet the threshold of the protocol. Finally, some recommendations are made to improve the indoor quality of the classroom as well as the students' health.

Keywords
Wellbeing Indicators, Health of students, International Well Building Standard, Experts' Opinions, Indoor quality

Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners. I understand that my thesis may be electronically available to the public.

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List of Abbreviations

IAQ .... Indoor air quality
IEQ .... Indoor environment quality
SW .... Student's wellbeing
ST .... Student
IWBS .... International well building standard
BREEAM .... Building Research Establishment Environmental Assessment Method
LEED .... Leadership in Energy & Environmental Design
STAR .... Sustainability tools forassessing and rating communities
UI .... University Indonesia
Polito .... Politecnico di Torino
WHO .... World Health Organization
ASHRAE .... American Society of Heating, Refrigerating and Air Conditioning Engineers
HVAC .... Heating, Ventilating & Air Conditioning
MERV .... Minimum Efficiency Reporting Value
UTA (AHU) .... Air handling unit
IQ .... Indoor Quality

1

Introduction

As social concepts, well buildings are constructed and related to a pre-built environment which fulfills with complicated and contextual well definitions. Generally, a well building or space considers various fields as the following list:

1. User's exposition with indoor environmental risks should be avoided.
2. Consider policies to provide a healthy lifestyle for the people.
3. Spatial arrangements should be considered for the users due to having a healthy lifestyle.
4. Enhances the active lifestyle [80].

The "healthy lifestyle" includes a variety of fields such as self-protective behaviors to decrease the risk to the minimum, and maximize wellbeing such as a healthy diet and eating, physical activity, drug usage avoidance, kinds of self-protection aspects like sexuality protection and also sun protection [44]. A close relationship exists between well buildings and people who care about their healthiness and wellbeing issues. Therefore, promoting the level of health and wellbeing is necessary for the cognitive, emotional, social and academic development of youth through using integrated and united approaches [5]. Environment and people are two essential elements that sustainable wellbeing highly depends on them [45]. Since the 1960s, researches on human thermal comfort started [18] and nowadays, it has been one of the important basis for several comfort patterns and standards [4], which cause the design and operation of internal environmental systems. Based on statistics, more than 90% of people's time is spent inside different kinds of buildings such as office, home, school, and factory [1]. Occupant productivity is under the impact of indoor Environment Quality (IEQ) [35]. So, for improving the comfort and wellbeing, the indoor environmental quality (IEQ) of buildings must be adequate for the building's occupants. Occupants' wellbeing can be affected by various indoor factors. Thermal, visual and acoustic factors are some of them [41, 42, 77]. So, a "better indoor environment" means adjusting a situation that a better thermal and light comfort feeling and indoor air quality are provided in. Researches have indicated that IEQ has a significant effect on different aspects of human, like healthiness, anxiety, productivity, and wellbeing [20]. Also, problems of building's indoor environmental quality (IEQ) (thermal, acoustic, visual and air quality) directly affect the comfort, health and productivity of the occupants [71]. Accordingly, occupant mood and performance is associated with healthy indoor air as well as acoustic, thermal and visual comfort [19]. Among all kinds of buildings, universities are the most challenging buildings where have more chances to influence students' health. One of the main and growing bodies of research contributes that canteens in the workplace and university have also been recognized as sites that are potentially important in health interventions [17, 3]. However, there is no enough information available to understand the amount of influence of environmental parameters on discomfort sensations and student performance, increasing students' health can, directly and indirectly, cause the enhancement of academic success [47]. Students spend a lot of their time in classrooms which is important for their educational success and it surely has more impact on their long-term health. By improving the students' health, universities discuss its importance and provide support methodically [51]. The increase of

students' health is revealed as a significant approach to developing students' social, emotional and academic qualifications and an important contribution to the on-proceeding battle to prevent youth depression, suicide, self-harm, substance abuse and antisocial behavior (bullying and violence) [70]. Sustainability evaluation tools must address relevantly suitable issues of major significance to campus environmental, social and financial endeavors and impacts. Since numerous aspects of colleges and universities, potentially fall under the rubric of sustainability, the issue here is miserliness. As specific measurement possibilities are the role of the creator and user of assessment tools, identifying issues with a wide domain of effects and influences are some other tasks. Additionally, the tools must present procedures to emphasize sustainability-related issues [66]. The research hypothesis is that students feel endure when they discomfort. This issue affects them, and their performance decreases in the long-term. It has captured that increasing indoor environment quality (IEQ) in university classrooms will help to improve the academic success of students, according to different kinds of studies. Hence, more investigation concerning student's wellbeing should be done in the educational buildings. This study analyzes diverse assessment tools in the field of occupants' health and wellbeing, and their correlation to IQs. By focusing on the selected subject, improving indicators and merging them into policymaking, and also developing associated tools is needed [39]. And by comparing diverse assessment tools, the main indicators which have relation to indoor environmental quality and also have some effect on students', are investigated. The focus of the literature review is on Educational buildings. This research aims to establish a connection between IEQ indicators, health, and wellbeing of educational buildings' occupants which are students and it may declare to the designers of this kind of buildings to apply the green practices in building design.

1.2 Problem statement & Research background

In this section, different issues have been considered to detect the impacts of the indoor environment on the health of students within the educational buildings. Building performance is a main concern in the building industry and one of the major issues in sustainable construction is environmental building performance assessment [11]. The built environment has a deep influence on the human's natural environment, financial state, health, and productivity [53]. So nowadays it has become a concern to how improving construction practices to minimizing their harmful and damaging effects on the natural environment [9]. This study is stimulated due to two main concerns; the first concern is of occupants have more worries about indoor air quality, comfort, healthiness and safety issues [8]. For more explanation; low Indoor air quality (IAQ) impacts people's performance [79] and existing issues with indoor environmental quality (IEQ) of a building have a certain effect on comfort, health, and productivity of the occupants [71]. This has largely been understood by the awareness that IEQ issues lead to sick building syndrome [35]. The second concern is the relation between indoor environment quality (IEQ), indoor air quality (IAQ) and student's health. Following different studies [78, 71], since the level of IEQ and IAQ reduces during the time, students feel more discomfort. Low indoor air quality level and high temperature hurt students' performance. [73]. Based on a primary study, it is found that there is an association between inadequate ventilation and student academic performance [63]. Thermal discomfort feeling in school or university has a direct relationship with reducing attention, concentration, productivity, and comfort [37]. Figure 1 demonstrates both indoor quality factors (IAQ & IEQ) and their effects on students' health at different levels. As shown in the figure, low IAQ and IEQ levels affect people's performance and occupants' productivity respectively. Considering students who are inside the classroom; the least level of indoor quality factors (IAQ & IEQ) causes the most rate of discomfort among them. In other words, students feel unsatisfied when the IAQ and IEQ rate is low in the classroom and their academic achievement and performance reduced in the long-term.

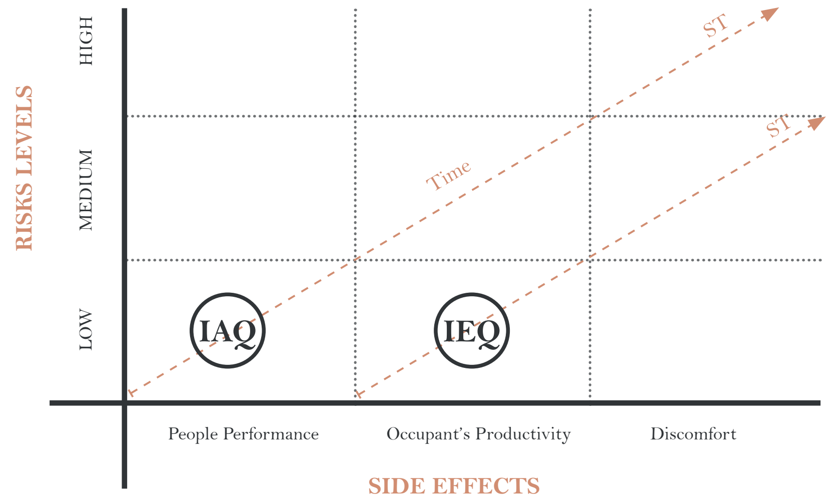

Figure1. Schematic overview of research problem statement

Indoor Air Quality .... (IAQ)
Indoor Environmental Quality .... (IEQ)
Students .... (ST)

Based on the results-driven from the graph, more attention should be considered to the building performance especially in the concepts of the high level of IAQ, increased ventilation, control, and confirmation of thermal comfort, and daylight wherever adequate. Sustainability issues should be considered as a standard in all educational buildings' development around the world. Also, the government should play a strong role to ensure the achievement of such issues to emphasize the significance and strategies of attaining a sustainable built environment. Universities should have leading attempts in sustainable environmental improvement. The essential step to decrease the level of all these concerns is to realize the sustainability of educational buildings, which highlights the necessity of sustainability rating tools to evaluate the performance of educational buildings and, to reduce their harms on the student's health, by taking into attention environmental and social concepts [26].

1.3 Research questions

The discussion of relevant problems has outlined that wellbeing is a complex topic and the management of student's health and occurrence of indoor comfort in the educational buildings is a unique challenge for people. Questions structuring this inquiry can further be broken down into Q1 and Q2, outlined below.

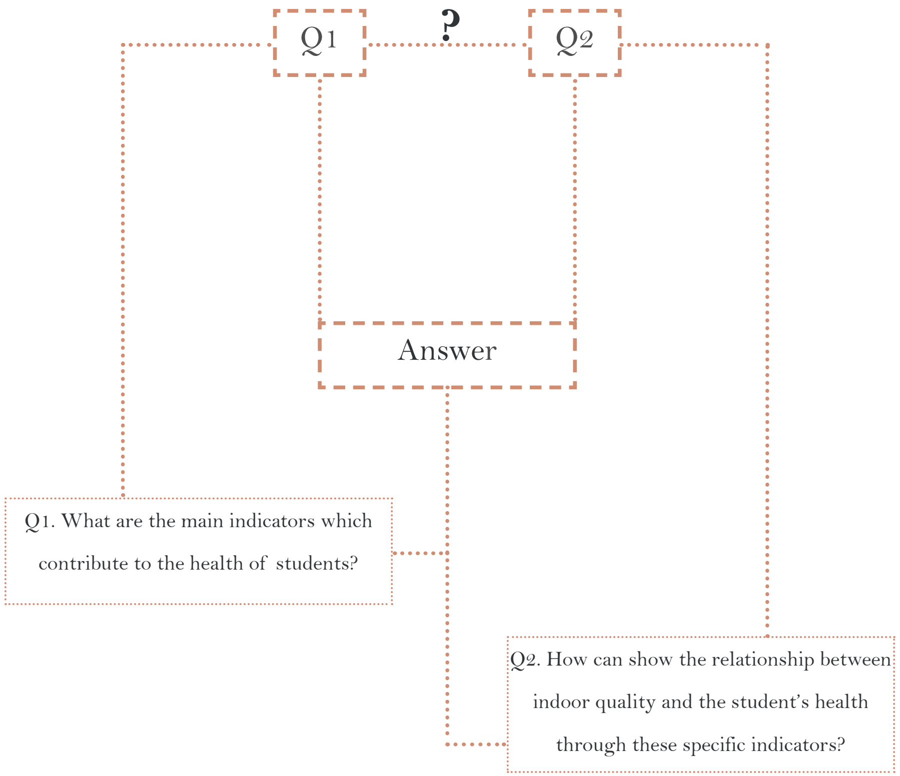

Figure 2. Schematic overview of research questions

Q1. This part explains "What is Student Wellbeing", investigating a variety of definitions of this concept which leads to identify different indicators related to the students' health. It is as important as all educational buildings like universities are working to a shared vision and a series of indicators that define the importance of youth and their wellbeing [70]. There are insufficient definitions of wellbeing to be found in the academic literature and rarely any definitions of "student wellbeing" [21]. While most educators and psychologists advise focusing on student wellbeing, there are very few agreements on the definition of students wellbeing. [10, 5] Have also lamented the absence of an appropriate conceptualization of wellbeing especially when applied to students [31]. There is a wide range of subjective hypotheses about the key components of wellbeing. [46] It is asserted that wellbeing equals the everyday term "happiness" but some others disagree, and their reason is that happiness is in the short-term but wellbeing is rather stable and experienced over time. In terms of wellbeing, different professional disciplines have taken on different prospects. As the clinical and health prospect tends to define, wellbeing is the absence of unfavorable conditions such as depression, anxiety, or abuse of substances. Modern psychologists generally prefer to operationalize well-being in terms of happiness and life satisfaction [70] and/or a major number of positive self-attributes [70, 57]. It is necessary to find the main indicators contributing to health after clarifying the description of student wellbeing. For this purpose, it has been recommended to explore and study different assessment tools to realize and know all the significant indicators influencing the health of the students.

Q2. Consideration of how best to monitor and assess and continue to adapt and create a healthy campus environment is important [15]. Interventions and a common understanding of what they want to achieve to build relationships across the campuses environment and students' health are required. It is due to Educational buildings that will face increasing firefighting demands and rely on services managed somewhere else without a strategic overview of how to improve wellbeing and how to use resources to intervene early.

1.4 Research objective

This research project brings expert's experiences and perspectives around about what can be done to adequately manage wellbeing in the educational buildings. The research hypothesizes that students suffer when they feel discomfort and their performance decreases during the time. According to various studies, it is captured that increasing indoor quality in university classrooms will help to improve academic achievement among students. Therefore, more exploration regarding student's health has to be done into the educational buildings. The main focus of the study is to identify how different assessment tools analyze the impact of the indoor quality (IQ) on the health and wellbeing of students. Thus, selecting an assessment tool applicable on the educational buildings and identifying the most important wellbeing indicators which significantly affect the health of students in a university classroom is the specific purpose of this thesis. Towards the achievement of this objective, comparing and assessing the wellbeing protocols is a fundamental point to investigate the relation between campus settings and student's health. Figure 3 shows the schematic design of the main objective of the thesis as it has outlined below:

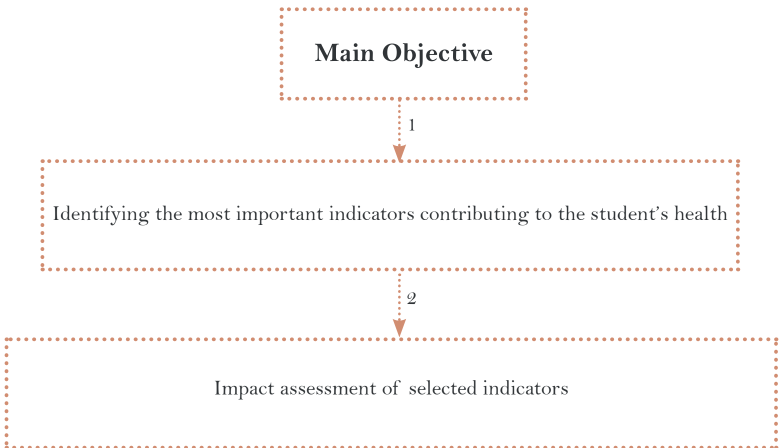

Figure 3. Schematic overview of research objective

1.5 Thesis Outline

This research will overview and assess the current environmental building rating tools used in different countries in terms of their characteristics in assessing building sustainability on occupant's wellbeing point of view and analyze the relationship between different indoor environmental parameters (humidity, ventilation, and light), and student's health over the campuses. The thesis was divided into five chapters: **Chapter1** is dedicated to the primary introduction about well buildings, problem formulation, and research background, research questions which are about the main indicators contributing to the student's health and selecting the indicators considering their effect on the student's health as the main objective of this thesis. **Chapter2** surveys major lines of research on the health of students through a review of literature and customize the categories and criteria points of well-known sustainability assessment tools regarding their priorities on the health and wellbeing. **Chapter3** represents the methodology part of the research which started with the comparison of three assessment tools namely at UI Green Metric, Star and International Well Building Standard, to select a protocol with the most concentration on the health and wellbeing of students. Then, it discusses finding a set of indicators from the selected protocol and filtering them according to expert opinions. Finally, a brief description of the case study is provided. **Chapter 4** presents the results of protocol and indicator selection, then shows the application of methodology on the case study. In addition, the impact assessment of indicators and the data verification are represented according to the protocol target. Finally, some reccomendations are provided by the relevant experts considering the case study. **Chapter 5** provides the conclusion part and summarizes the results of the research, discusses the main findings, and contains a proposal for the future development of the studied case study to improve indoor quality as well as students' health. Also, the work limitations while doing the research process are explained in this part. Figure 4 shows an overview of the research design structure and thesis outline.

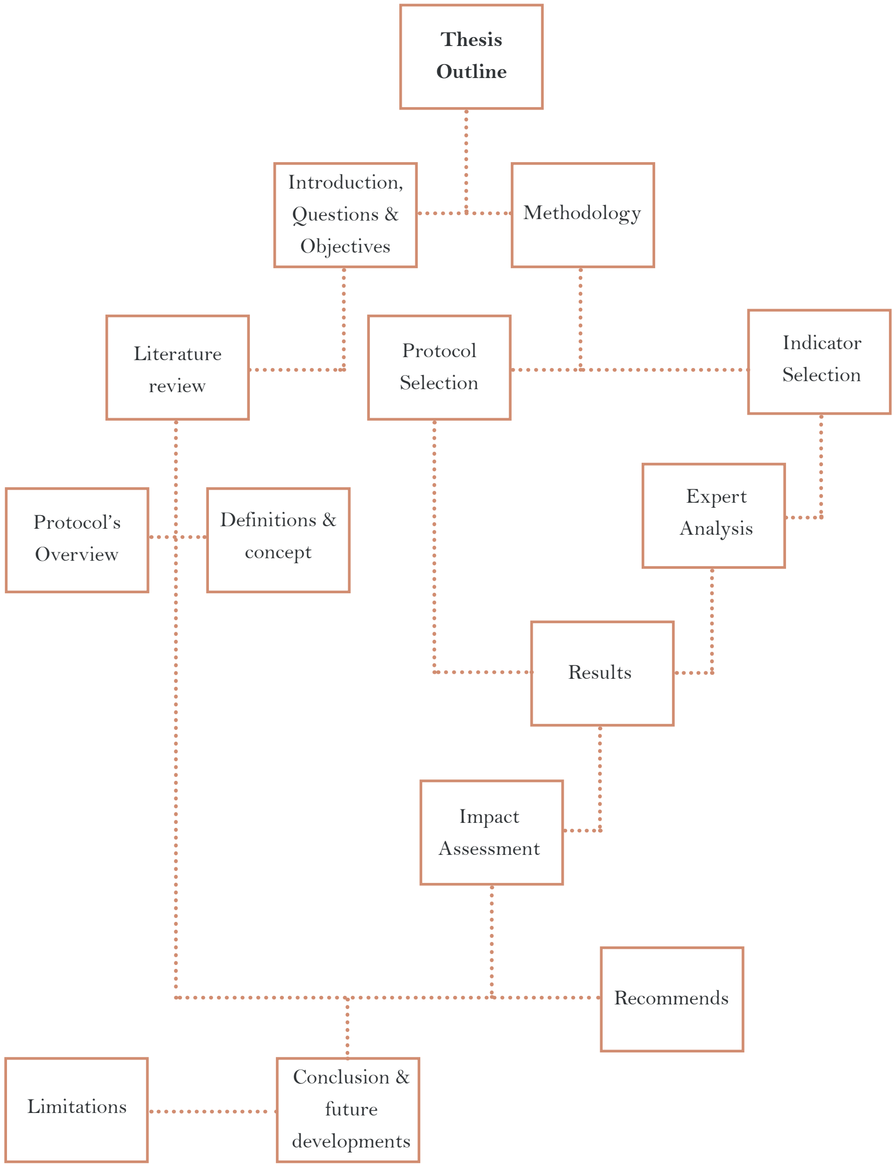

Figure 4. Schematic overview of the research design structure and thesis outline

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Literature review

Over the recent ten years, there has been a slow progress shift in both research and school practice to move from the concept of student welfare towards the concept of student wellbeing. This trend towards healthiness is stable with a positive psychology approach [58, 60] and also with the recent positive education approach [64, 47, 60] focused on wellbeing and its determinants. In 1947, the World Health Organization (WHO) described health in terms of wellness, which is physical, mental and social wellbeing, not just the lack of illness. It is also argued that schools should be committed to training youth who are capable and confident to face the ups and downs of life [13,70]. In that case, it is suggested that schools have to focus on developing the wellbeing of students to create happier, healthier and more productive young people who flourish as human beings. Research has resulted in students at a high level of wellbeing appearing to be better at solving problems, showing better work results, having more positive and meaningful social communication, displaying more virtues such as forgiveness and kindness, being more resistant to stress, and achieving better physical and moral health[22,72]. Health equity has been defined as a situation in which all persons can reach their full health potential and are not disadvantaged from attaining it due to nationality, ethnicity, religion, gender, age, social class, socioeconomic status, sexual orientation or other socially determined conditions. In general, health diversities are reflected by common differences in the spread of chronic diseases (e.g., diabetes) among the highest and lowest income and education groups of people [12]. The necessity to be healthy and positive is to stay in environmentally and friendly places where have good indoor quality. In a building, an important element for building occupants to comprehend good health and comfort level is the indoor environment quality (IEQ) [49]. The outdoor environmental quality and also pollutants produced indoors influence IEQ. The correlation between IEQ, student health, attendance, and performance have been demonstrated in some researches [65]. It is necessary to search and realize various assessment tools to evaluate the indoor quality of a building because each building type may have different IEQ features, which could be somehow attributed to building age and construction materials. In other words, different buildings indicate different environmental quality results to the indoors and the occupants[49]. Thus applying different criteria of building assessment tools can analyze three aspects of sustainability; environmental, economic, and social; and can realize the building condition and IEQ level of the building. Most building assessment methods deal with a single criterion such as energy use, indoor comfort or air quality to show the broad performance of a building [44]. As environmental issues become more urgent, to assess building performance across a broader range of wellbeing criteria, require more comprehensive building assessment methods[11]. Therefore, many of these environmental assessment tools cover the building level and are based on some kind of database of lifecycle assessment[58]. All assessment tools represent the need to decrease the usage of energy, water, and other materials and inputs in buildings. Tools that orient toward sustainability incorporates goals of arranging the throughput to an equivalent level with ecosystem carrying capacities [66]. Focusing on wellbeing, the following literature review will start with an overall overview of different assessment tools on building and campus level. Consequently, a full description of these campus-related assessment tools will be presented.

2.1 Overview of existing assessment tools

Environmental building assessment techniques make a significant contribution to understanding the relationship between buildings and the environment [8]. A considerable number of assessment tools have also been developed to assess the environmental effects of construction since the 1990s. As there are many sustainability rating tools, each of them differs in their structural features, which are the assessment attributes, the weighting schemes, the assessment model implemented, and the assessment ranking based on their country of origin [30]. Such rating systems had been developed in different countries including LEED in the USA, BREEAM in the UK, Malaysia's Green Building Index, etc. The Building Research Establishment Environmental Assessment Method (BREEAM) was the first method of the environmental assessment of buildings in the 1990s and still the most extensively used method[38]. BREEAM system has been continuously updated and expanded to include assessment of buildings such as existing workplaces, malls, new homes, and light industrial buildings[77]. BREEAM checklist consists of eight categories: Energy, Water, Transport, Materials, Health, Land use, Pollution and Waste management. Following the launch of BREEAM in the UK, many other assessment tools, such as LEED, have been developed all around the world to carry out an environmental building assessment. LEED System was first published in 1999, helping to improve the quality of buildings and their influence on the environment. By identifying performance in five main areas of human and environmental health, LEED promotes a whole-building approach to sustainability [23]. LEED checklist consists of six branches: site selection water efficiency, energy and atmosphere, indoor environment, materials used, and process of innovation and design. In addition to the above-mentioned rating systems, there are other well-known rating tools such as STAR, UI Green Metric and IWBS, that have been seeking to establish global sustainability towards campuses. There is a description of all the assessment tools studied in this research. The environmental building assessment tools used in various countries and years are summarized in Figure 5.

Regarding the figure, five assessment tools have been reviewed vary greatly in purpose, scope, and function. Following the grade of applicability of the above-mentioned assessment tools, three protocols; STAR, UI Green Metric, and IWBS are related to the campuses and the other two; LEED and BREEAM associated with the buildings. The origin and date of each protocol and their macro-categories are described respectively. For example, the origin of BREEAM is United Kingdom and the date of establishment is 1990. The scale of BREEAM is buildings and it applies to the buildings level. The categories of BREEAM are Energy, Water, Transport, Materials, Health, Land use, Pollution, Waste Management. In addition, LEED came 10 years later from USA to assess the buildings in the areas of Sustainable Site, Water Efficiency, Energy &Atmosphere, Materials &Resources, Indoor environmental Quality, Innovation & Design, Regional Priority. These mentioned tools share significant information about various criteria and indicators which have been expanded to observe particular aspects of environmental building performance. By identifying important issues as well as methods, these tools provide a foundation for strategic planning to set and achieve prioritized sustainability goals. For the further stages of the study, the educational buildings are centralized and only those assessment tools applicable to the campuses namely at STAR, UI Green Metric and IWBS are considered. In the section ahead, these tools are discussed in detail.

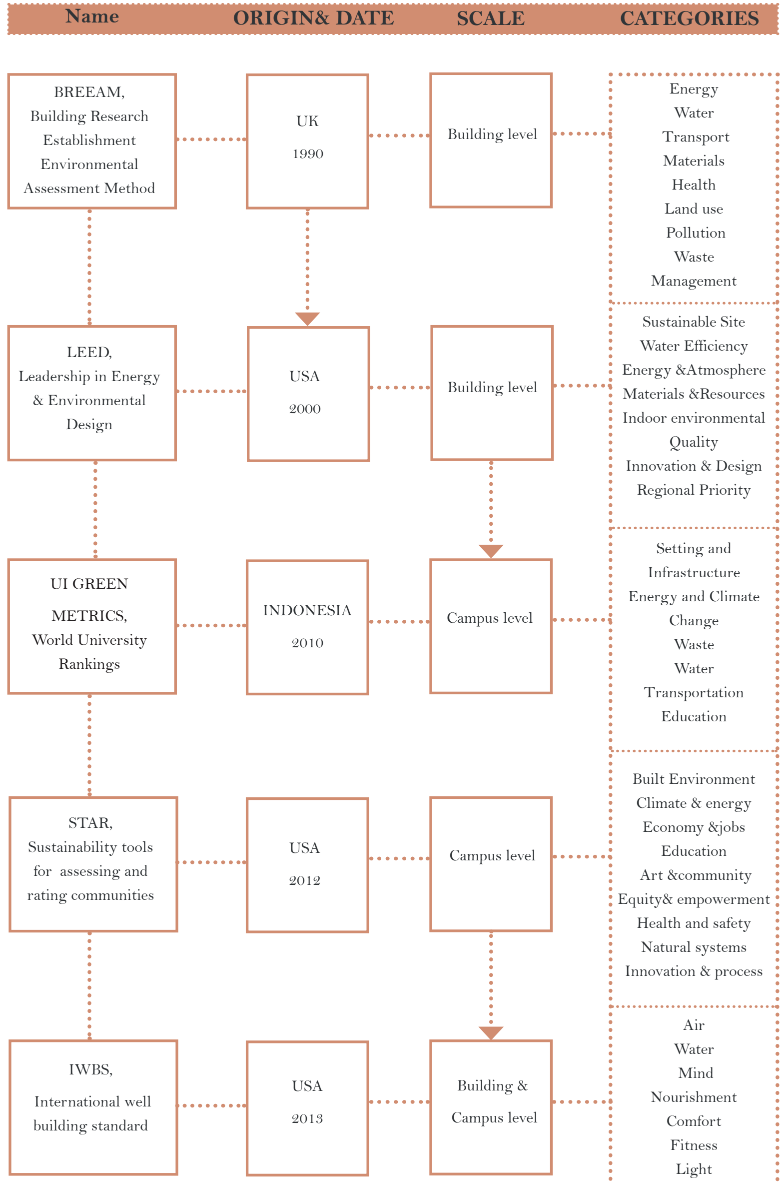


Figure 5. Summarization of environmental building assessment tools

2.1.1 STAR Framework of Sustainability

The STAR Community Rating System is the national leading framework and certification plan for local sustainability. The publish of STAR in 2012 marked a great milestone in the sustainability movement. Hundreds of stakeholders worked together by consensus to deliver a common framework for sustainability with nationally admitted standards for determining the depth and width of the social, economic, and environmental issues that our nation's cities and countries are facing. The measures and procedures of the rating system have inspired local leaders to do some work over the past four years, including being more inclusive, making equitable investments, advance work on climate, integrate health into sustainability considerations, collaborating within and across departments and build broader community support, both with residents and the business community. The STAR framework, which completes the economic, environmental, and social sides of sustainability, provides communities with a menu-based system to customize their approach based on local circumstances and preferences [68]. Star's eight categories are Built Environment, Climate & Energy, Equity & Empowerment, Health & Safety, Education, Arts & Community, Economy & Jobs, Natural Systems, Innovation & Process. Figure 6 indicates the different categories and indicators of STAR protocol which has been published in 2012.

Figure 6. Overview of criteria and indicators of STAR protocol

2.1.2 UI Green Metric framework

In April 2010, University Indonesia (UI) initiated a world university ranking to measure campus sustainability efforts, which later known as UI Green Metric World University Ranking. It was considered to make an online survey to show sustainability programs and policies in universities all around the world. Green Metric was not based on any available ranking system. However, it was developed with an awareness of several existing sustainability assessment systems and academic university rankings. Sustainability systems that were referential to during the design stage of Green Metric are Suatainable, Tracking, Assessment and Rating System (STARS) and LEED. The instrument generally adopts the concept of environmental sustainability with three elements, i.e. environmental, economic, and social. The environmental aspect includes the use of natural resources, management of the environment and avoidance of pollution, while the economic aspect includes profit and cost savings. Education, community, and social involvement are the sections of the social aspect. UI Green Metric criteria [25] captures these three aspects. UI Green Metric World University Ranking is open to global participation, contributes to the academic discourse on sustainability in education and campus greening, encourages university-led social change in sustainability areas and is in line with the UNESCO program of Education of Sustainability in Higher Education.. One of Ranking's aims is to encourage universities around the world to look and self-evaluate their policies and position in the struggle against global climate change [52]. The protocol includes six categories, including Setting & Infrastructure, Transportation, Energy & Climate Change, Education, Waste and Water. These categories focus on the three aspects of sustainability; environmental, economical and social. The UI Green Metric indicators belong to different criteria and show different building goals for achieving an appropriate level of sustainability. Focusing on the social aspects of sustainability in the protocol is more relevant to the scope of this study. The aim is to determine which indicators are based on occupants' health and wellbeing. Figure 7 shows the different UI Green Metric protocol categories and indicators which has been published in 2010.

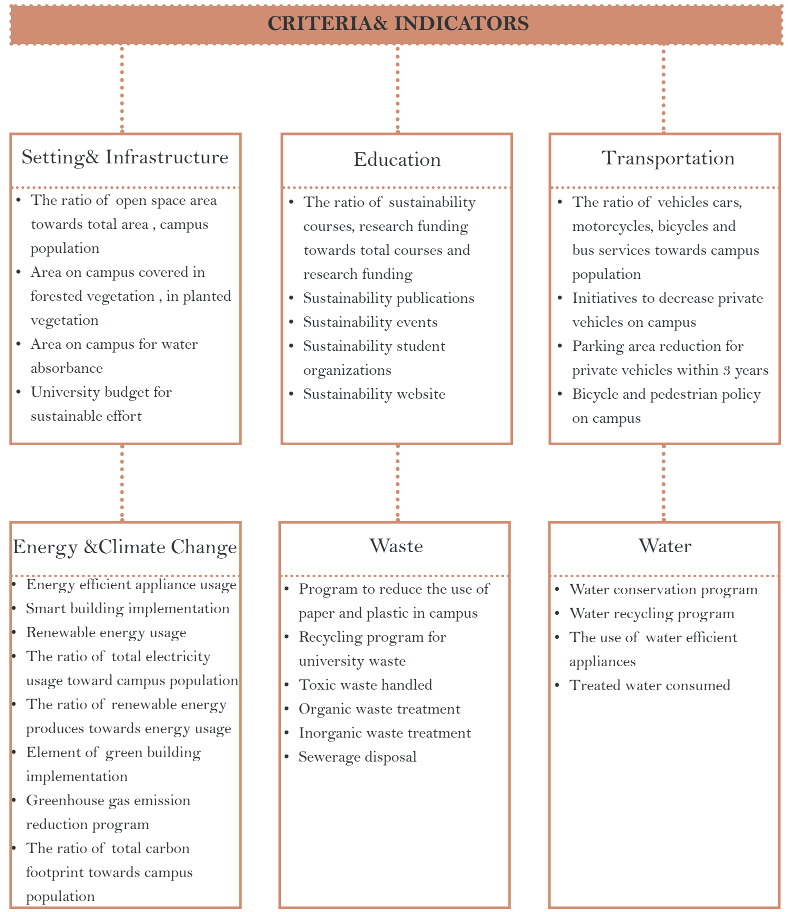


Figure 7. Overview of criteria and indicators of UI GREEN METRIC protocol

2.1.3 International Well building standard framework

Techniques to improve human health and wellbeing have played a rather small role in building standards evolution over the past decade. It is time to increase and grow human health and comfort to the forefront of building practices and reinventing buildings that are good not only for the earth but also for people[75]. WELL presents 105 performance indicators, design techniques, and policies to be implemented by building's owner, designers, engineers, contractors, users, and operators. This is based on a complete review of the available research about the influences of spaces on each individual and has been advanced through technical and scientific review. The WELL Building Standard combines best practices with evidence-based health and wellness interventions in design and construction. As a vehicle, it harnesses the built environment to hold up human health, wellbeing, and comfort. WELL Certified spaces and developments result in a built environment that helps improve their occupants' health, wellness, mood, sleep, comfort, and performance. This is partly attained by performing strategies, programs, and technologies designed to inspire healthy, more active lifestyles and lessen occupant subjection to harmful chemicals and pollutants. Educational Facilities are initial spaces in the domain of the WELL Building Standard. For several hours nearly every day, educational buildings can place students. The educational building's environment must accommodate a number of different functions and contexts types while keeping its occupants safe, healthy, and happy [75]. The protocol of the WELL Building Standard is divided into seven wellbeing categories: Air, Water, Nourishment, Light, Fitness, Comfort and Mind. The seven concepts are made of 105 features. Each feature is separated into sections that are often adjusted to a specific type of building. There are one or more requirements within each section that dictate specific parameters or measurements to be fulfilled. The IWBS offers an innovative approach to green building systems that focus on the wellbeing of the user. This protocol considers social concepts of sustainability very deeply and it has a variety of targets to achieve a healthy lifestyle. Figure 8 shows the various categories and indicators of IWBS protocol that has been published in 2013.

CRITERIA& INDICATORS

Air
- Air quality standards
- Smoking ban
- Ventilation effectiveness
- VOC reduction
- Air filtration
- Microbe and mold control
- Construction pollution
- management
- Healthy entrance
- Cleaning protocol
- Pesticide management
- Fundamental material safety
- Moisture management
- Air flush
- Air infiltration management
- Increased ventilation
- Humidity control
- Direct source ventilation
- Air quality monitoring and feedback
- Operable windows
- Outdoor air systems
- Displacement ventilation
- Pest control
- Advanced air purification
- Combustion minimization
- Toxic material reduction
- Enhanced material safety
- Antimicrobial surfaces
- Cleanable environment
- Cleaning equipment

Nourishment
- Fruits and vegetables
- Processed foods
- Food allergies
- Hand washing
- Food contamination
- Artificial ingredients
- Nutritional information
- Food advertising
- Safe food preparation material
- Serving sizes
- Special diets
- Responsible food production
- Food storage
- Food production
- Mindful eating

Comfort
- ADA accessible design standard
- Ergonomics: visual& physical
- Exterior noise intrusion
- Internally generated noise
- Thermal comfort
- Olfactory comfort
- Reverberation time
- Sound masking
- Sound reducing surfaces
- Sound barriers
- Individual thermal control
- Radiant thermal comfort

Light
- Visual lighting design
- Circadian lighting design
- Electric light glare control
- Solar glare control
- Low-glare workstation design
- Color quality
- Surface design
- Automated shading and
- dimming controls
- Right to light
- Daylight modeling
- Daylighting fenestration

Mind
- Health and wellness awareness
- Integrative design
- Post-occupancy surveys
- Beauty and design I
- Biophilia I – qualitative
- Adaptable spaces
- Healthy sleep policy
- Business travel
- Building health policy
- Workplace family support
- Self-monitoring
- Stress and addiction treatment
- Altruism
- Material transparency
- Organizational Transparency
- Beauty and design II
- Biophilia II – quantitative
- Innovation feature I
- Innovation feature II

Water
- Fundamental water quality
- Inorganic contaminants
- Organic contaminants
- Agricultural contaminants
- Public water additives
- Periodic water quality testing
- Water treatment
- Drinking water promotion

Fitness
- Interior fitness circulation
- Activity incentive programs
- Structured fitness opportunities
- Exterior active design
- Physical activity spaces
- Active transportation support
- Fitness equipment
- Active furnishings

Figure 8. Overview of criteria and indicators of the IWBS protocol

3 Methodology

To achieve the above research objectives and provide answers to the research questions an academically rigorous set of methods is used. This process is iterative and thus modified several times during the research stages. An in-depth literature review has provided an academic base for the project into two steps:

A. Collecting and evaluating five assessment tools; three campus level protocols such as UI Green Metric, STAR, IWBS, and two building-level rating systems like LEED and BREEAM.

B. Focusing on the three campus-level protocols regarding to the scope of the study. This is followed by a practitioner document analysis to select the protocol and wellbeing indicators. The methodology used for the selection of protocol and indicators is subdivided into the following phases:

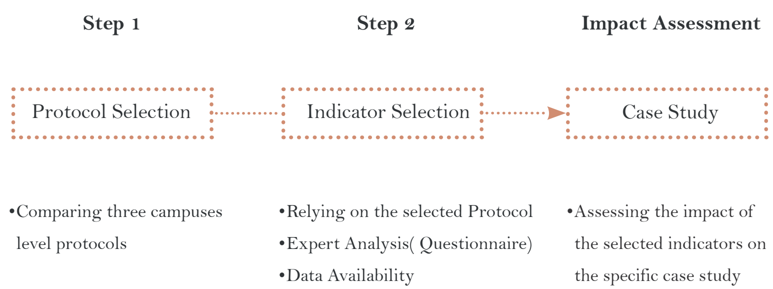


Figure 9. Schematic overview of research methodology

3.1 Protocol selection procedure

In this part, an investigation on the most popular and globally used schemes: UI Green Metric, IWBS, and STAR is done to identify the effectiveness and impacts of different aspects of the assessment criteria on the wellbeing of occupants. The result will be the selection of one assessment tool among the others to develop an effective sustainable assessment method for the case study focusing on the health of occupants. The selection procedure of the protocol is divided into three steps as described below:

1. Analysis the criteria of three protocols to check their effectiveness on wellbeing. Those criteria are taken into consideration that have the most impact on the health.

2. Comparing all the criteria and indicators by prioritizing the health of occupants to select the most appropriate protocol among them.

3. Classifying health and wellbeing aspects for better decision making on the protocol selection.

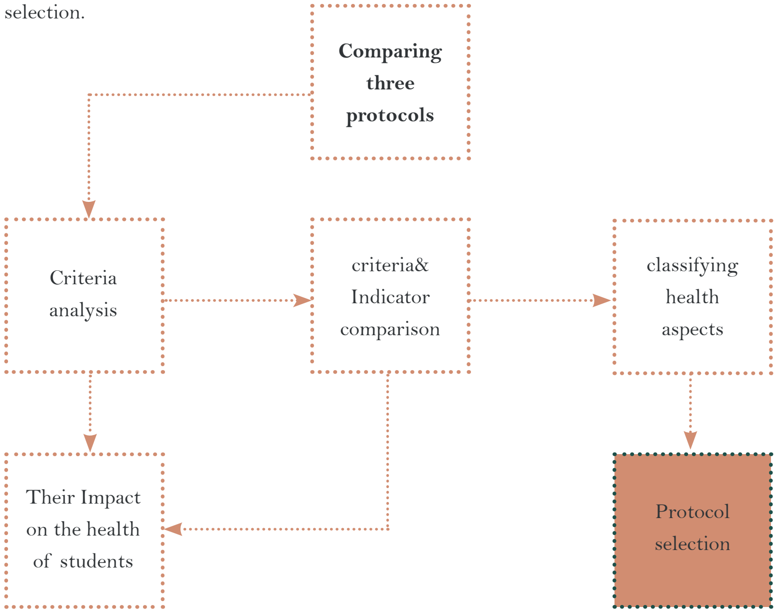


Figure 10. Schematic overview of protocol selection procedure

3.2 Indicator selection procedure

Selection of indicators is occurred through three sequential phases:

First phase accomplished in the previous part while selecting the protocol with comparing three campus assessment tools, recognizing their criteria and classifying health and wellbeing aspects. So, the first list of indicators improved preliminary after the protocol selection.

The **second phase** is developed by identifying the links and similarities between the most common and important indicators of three studied rating systems according to their contribution to the health of students.

In the **third phase**, tried to filter the list of indicators according to the case study, an online Questionnaire and the data availability.

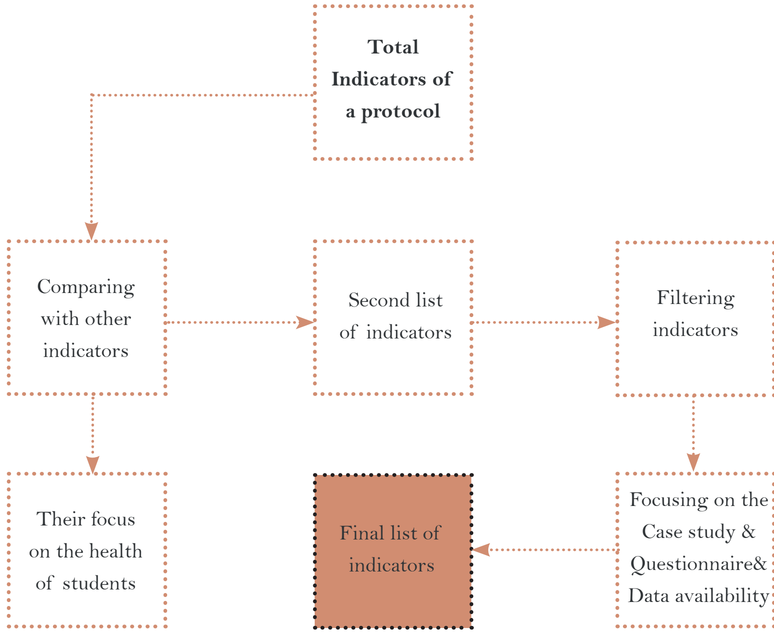


Figure 11. Schematic overview of indicator selection procedure

3.3 The case study

Politecnico di Torino (Polito) is one of the most respectable technical institutions in Italy and Europe. This institution was found in 1859 as Technical School for Engineers and later specialized for Engineering and Architecture. The Politecnico is made up of 9 campuses: Alessandria, Biella, Mondovì, Verrès, Castle of Valentino, Corso Duca Degli Abruzzi, Cittadella Politecnica, Design and Sustainable Mobility Citadel in Mirafiori and Lingotto. The Campus in Corso Duca Degli Abruzzi 24 (Figure 12) built-in 1958, is the main complex of the Politecnico. It has an area of 122,000 m2 and hosts the School of Engineering and the professors' departments. This campus, in the university nomenclature, is known as TO_CEN and divided into five big districts, known as TO_CEN01, TO_CEN02, TO_CEN03, TO_CEN04, and TO_CEN05.

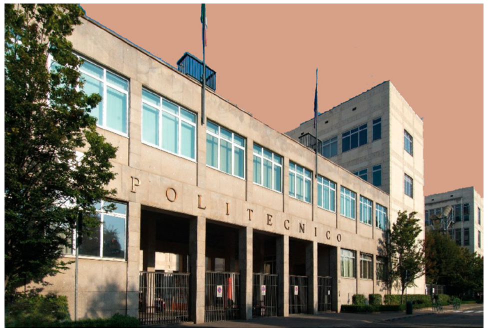


Figure 12. Politecnico di Torino, Campus in Corso Duca Degli Abruzzi

Source: http://www.museotorino.it/view/s/3a3ad0df47564f14bd936feb8a8cbe4d

The case study which is presented and evaluated is classroom 1 located on the main campus of Polito. The room area is about 318.11 m2, the room volume is almost 1460m3 and the maximum occupancy of the classroom is 408 seats. The operation hours are 8:00 am to 7:00 pm from Monday to Friday and from 8:00 am to 2:00 pm on Saturday. The data measurements of the place have begun from 2011 up to now. The internal photo of the classroom has shown in the figure 13.

Figure 13. Politecnico di Torino, Campus in Corso Duca degli Abruzzi, classroom1
Source: Photographs by Dr. Giovanni Carioni, Polito Data Lab, October 2018

Figure 13. Politecnico di Torino, Campus in Corso Duca degli Abruzzi, classroom1
Source: Photographs by Farzaneh Aliakbari, October 2019

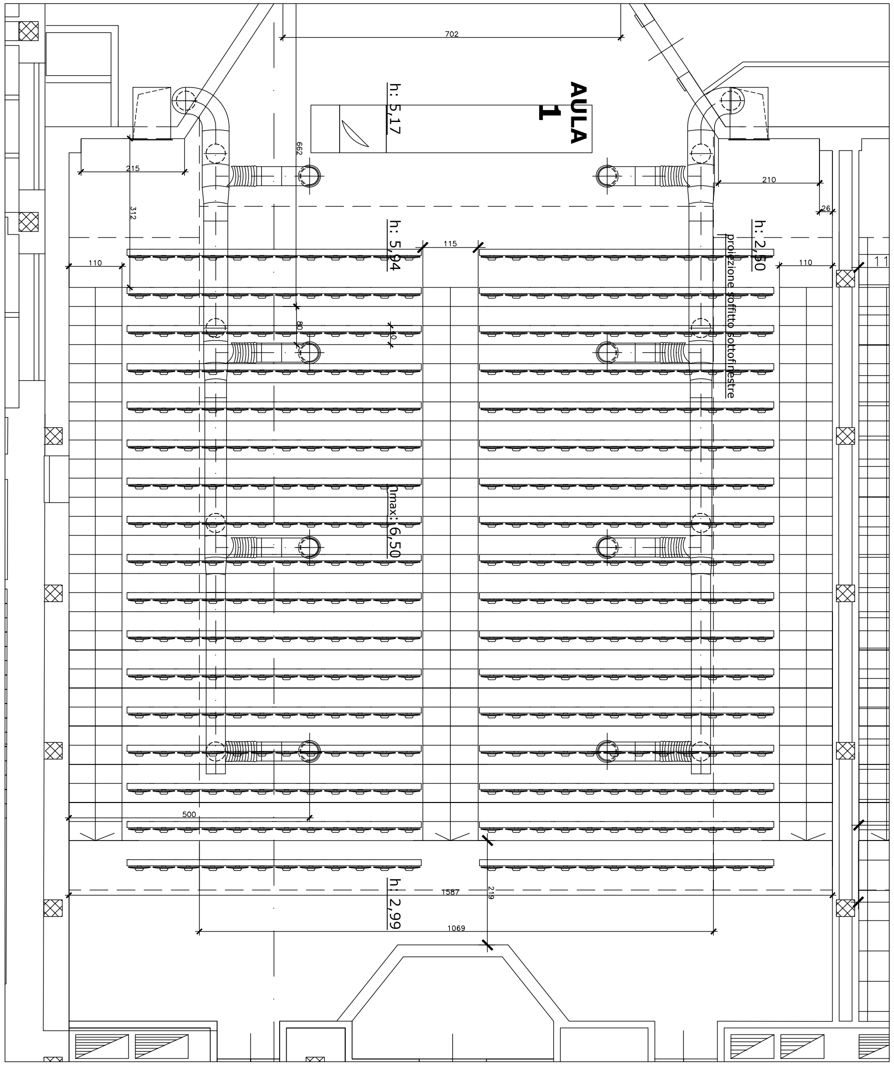


Figure 14. Plan of classroom 1, Politecnico di Torino
Source: Area Edilog, Polythechnic University of Turin, October 2019

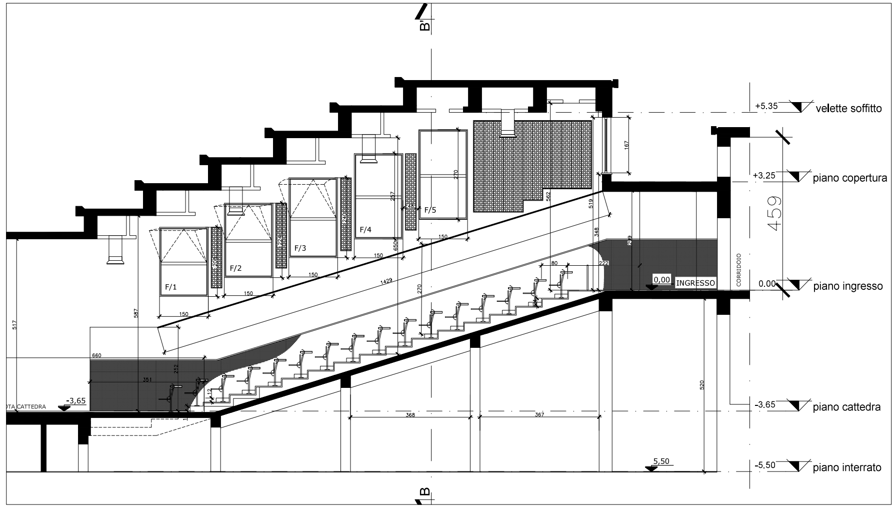


Figure 15. Section of classroom 1, Politecnico di Torino
Source: Area Edilog, Polythechnic University of Turin, October 2019

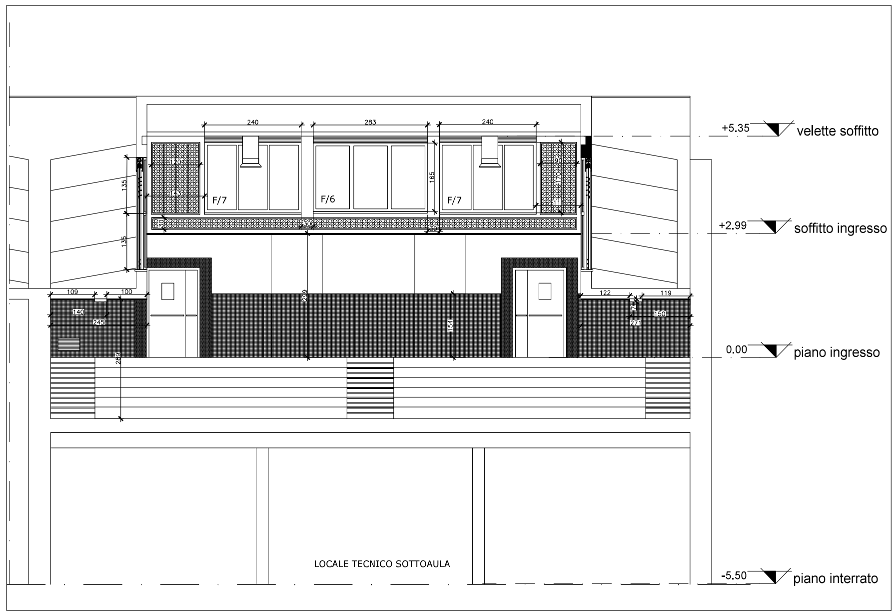


Figure 16. View of classroom 1, Politecnico di Torino
Source: Area Edilog, Polythechnic University of Turin, October 2019

4
Result

Following the methodological approach discussed in the previous chapter, the figure 17 outlines the findings of this research thesis. This chapter is followed by findings resulted from the application of the methodology on the case study which is divided into four parts as below:

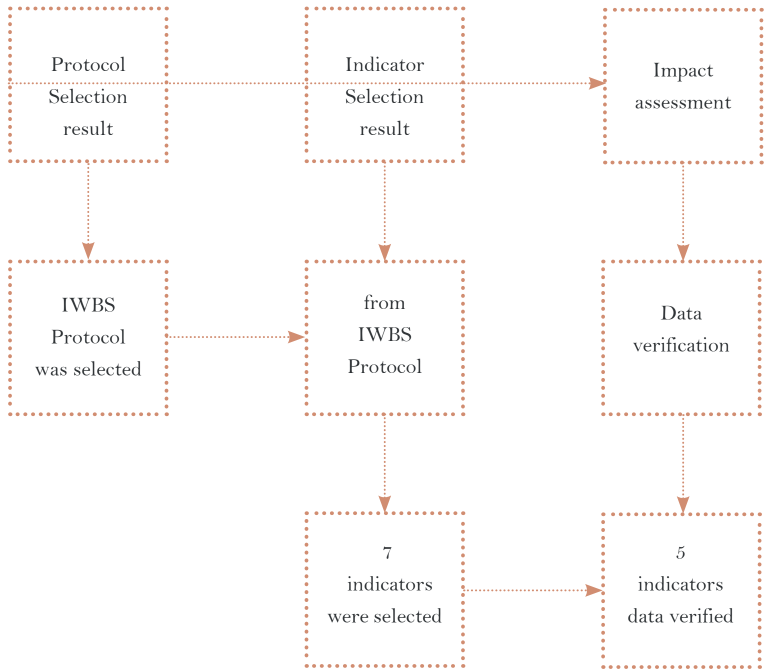


Figure 17. Schematic overview of results

4.1 Protocol selection result

In this part, the selection of one assessment tool among the others is considered as a vital point to allow the researcher to go on through the other steps of the study. The process of protocol selection outlined below:

4.1.1 Comparison of three assessment tools

The aim is to compare three of the campus assessment tools like STAR, UI Green Metric and International Well Building Standard (IWBS), to select the most appropriate one according to the wellbeing point of view. Following the literature review which has been done in the previous part, it is captured that, UI green metric protocol has been developed based on the environmental sustainability concept and it has less focus on the human health. While, Star and IWBS rating systems have more concentration on the wellbeing of occupants. The selection process has started with a comparison of the main categories within three protocols. As can be seen in figure 18, different categories of the star, UI green metric and IWBS have been overlapped according to their indicators. The color-coded categories are similar in their indicators. For example, four categories of IWBS protocol such as air, water, light, and comfort are similar to three categories of Star which are natural system, economy & job, climate & energy, and built environment. At the same time, they are similar to three categories of UI Green Metric called Water, Transportation and Energy & climate change. Continuing the overlapping process, it is captured that UI Geen Metric does not have a category similar to nourishment criteria in the IWBS and Economy & job criteria in the Star protocol. These comparisons have clarified many issues, for example, the UI Green Metric has more focus on environmental health rather than human health. Meanwhile, Star has moved toward concentrating on human health more than UI Green Metric. To conclude the comparison, there are six categories in the IWBS protocol which are matched with the other two protocols by focusing on the human health and its indicators shows that this protocol focuses more on the health of occupants.

Figure 18. Schematic overview of protocols comparison

By counting all the indicators of three assessment tools; IWBS, Star and UI Green Metric, it is understood that the total indicators of STAR are 49, and only 15 indicators (30%), focus on the wellbeing. Also, total indicators of UI Green Metric are 38, and 6 indicators (16%) focus on the health of occupants. Furthermore, the total indicators of IWBS are 105 and all of them (100%), focus on the health and wellbeing of people. These results lead to the selection of the IWBS protocol for the next part of the research. Figure 19 shows the total indicators of each protocol and the percentage of their focus on the students' health in the educational buildings.

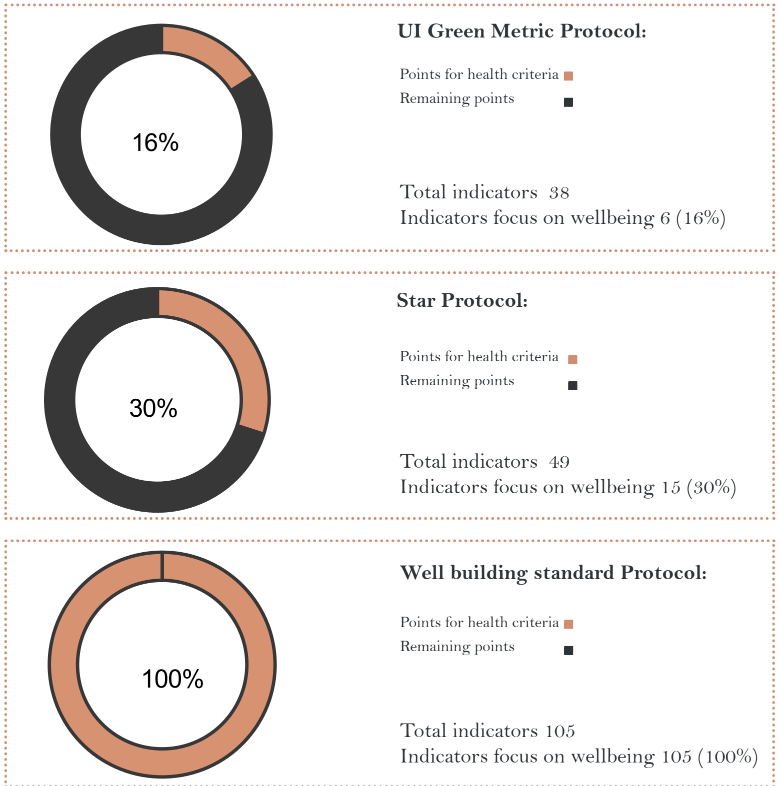


Figure 19. Diagram of indicator's percentage affecting student's health

The wellbeing of occupants involves thermal, visual & acoustical comfort and proper indoor air quality. Temperature and humidity levels provide helpful insight into the prevailing conditions that affect thermal comfort. Visual comfort is an integral part of proper IEQ and a critical design parameter in buildings since it improves productivity and overall functions. Also, indoor air velocity impacts thermal comfort conditions. Air ventilation and circulation play a dominant role in achieving comfort conditions and securing the necessary amount of fresh (outdoor) air by natural, mechanical and/or hybrid ventilation. On an urban scale, transportation infrastructures, including public transport, availability of safe bicycle routes, suitable pedestrian streets, etc., are major elements for sustainable urban development. Public safety and security are also important social aspects that influence the wellbeing of residents. Accessibility to public spaces (e.g. community centers and services, parks) and other services (e.g. broadband networks) are also very important social criteria [6]. Besides, some other important aspects that affect the health and wellbeing of people such as healthful food eating, water quality, daily physical activities and accessibility to the other facilities into the community. To conclude, wellbeing aspects are categorized into ten parts such as outdoor air quality, indoor air quality, visual comfort, acoustical performance, thermal comfort, accessibility, water quality, daily physical activities, healthful food, and sustainable transportation. After identifying wellbeing aspects, it is tried to match all the mentioned aspects with different categories of well building standard assessment tools which has been selected in the previous part to make a consonant framework for going on the research. Figure 20 shows the wellbeing aspects and well building standard categories which were linked together. For example, outdoor and indoor quality wellbeing aspects were matched to the Air category of IWBS and water quality aspect was linked to water criteria of the selected protocol. This framework provides a clear and intuitive format for evaluating IWBS on both building and campus levels. Because this protocol involves all the aspects of wellbeing and it can be used for selecting the wellbeing indicators according to their relevance to campuses.

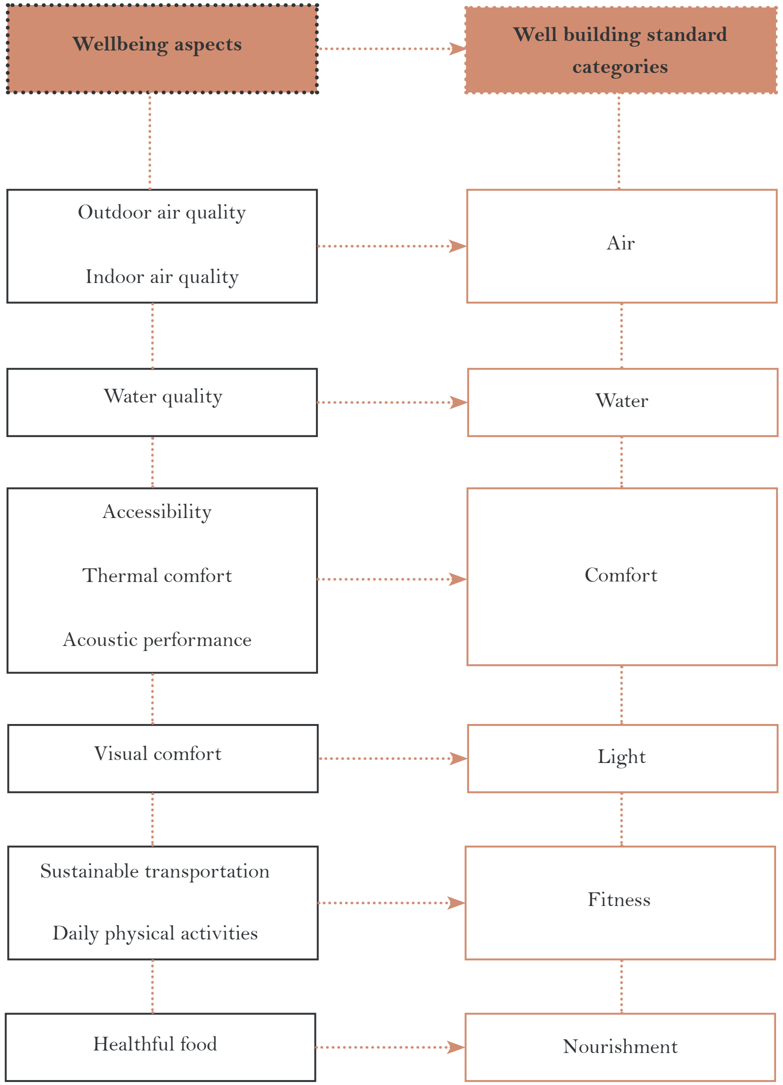


Figure 20. Confronting wellbeing aspects and well building standard categories

4.2 Indicator selection result

Departing from the research initiatives described in the previous section, the next step involves the selection of a set of indicators to assess the indoor quality of an educational building by overlapping the categories and indicators of three protocols considering wellbeing to find equivalent indicators among them and to select the most popular and common indicators contributing to the students' health from IWBS. Figure 21 shows the overlapping process of all the categories and indicators of three assessment tools. It can be seen from the figure that IWBS has an indicator called "Drinking water promotion" which is similar to the "Water recycling program" indicator in the Star protocol and "Community Water Systems" indicator of the UI Green metric protocol. Besides, all the three protocols have an indicator about " Greenhouse Gas" and they are focusing on reducing the greenhouse gas emission program and improving air quality. Also, all the three protocols concentrate on sustainable transportation and they have some indicators like Transportation Choices, Bicycle Storage Facilities for Schools and Bicycle and pedestrian policy on campus. IWBS protocol has many indicators related to the light category and some of them are matched with two other protocols' indicators like solar glare control and the ratio of total electricity usage towards campus population. They are focusing on using natural light and reducing electricity usage during the time. Going on the overlapping process, it has captured that three categories of UI Green Metric protocol namely at mind, comfort, and nourishment are not matched with the macro-categories of Star and IWBS. Therefore, this protocol does not have similar indicators to "Processed Foods", " Food Access & Nutrition access to fresh and healthful food", " Sound Reducing Surfaces", " Ambient Noise & Light Minimise", " Civil & Human Rights" and " Stakeholder Orientation". At the end of this stage, a list of indicators is selected from IWBS protocol according to their similarity to the other indicators used in Star and UI Green metric protocols.

Categories	Protocols	Indicators
Water	STAR	Community Water Systems/Water in the Environment
Water	IWBS	Drinking water promotion
Natural system	UI green metric	Water recycling program
Climate& energy	STAR	Greenhouse Gas Mitigation/Outdoor Air Quality
Air	IWBS	Greenhouse Gas Mitigation/Outdoor Air Quality
Energy & Climate Change	UI green metric	Greenhouse gas emission reduction program
Built Environment	STAR	Transportation Choices
Fitness	IWBS	Active Transportation Support- Bicycle Storage Facilities for Schools
Transportation	UI green metric	The ratio of bicycles found towards campus population Bicycle and pedestrian policy on campus
Health & safety	STAR	Food Access & Nutrition access to fresh and healthful food
Nourishment	IWBS	Processed Foods/Fruits And Vegetables
✕	UI green metric	✕

Categories	Protocols	Indicators
Built Environment	STAR	Light
Light	IWBS	Solar glare control
Energy & Climate Change	UI green metric	The ratio of total electricity usage towards campus population
Equity& empowerment	STAR	Civic Engagement/ Civil & Human Rights
Mind	IWBS	Stakeholder Orientation
✕	UI green metric	✕
Built Environment	STAR	Ambient Noise & Light Minimise and manage ambient noise and light levels to protect public health and the integrity of ecological systems
Comfort	IWBS	Sound Reducing Surfaces
✕	UI green metric	✕

Figure 21. Overlapping process of indicators

By the overlapping process, some indicators have been identified as the most common and important ones according to the wellbeing point of view. Thus, it has been decided to select those indicators with more concentration on the human health from IWBS protocol. The second list with 47 indicators categorizing in seven parts; air, light, comfort, nourishment, mind, fitness and water has been improved. The selected indicators have been matched with wellbeing aspects and the number of them has been kept to the minimum, tried to associate a restricted number of clear and distinctive parameters to each wellbeing objective. Table 1 shows the list of indicators selected from IWBS protocol and their connection with wellbeing aspects.

Table 1. List of indicators selected from IWBS raised by protocols comparison

Wellbeing Aspects	Well Building Standard Category	Indicators
Accessibility	Comfort& Fitness	**72.p1.** Accessible design - Accessibility and Usability **P8.p2.** Injury Prevention- Sidewalks **P8.p3.** Injury Prevention- Crosswalks **P8.p4.** Injury Prevention- Safe Routes to School
Daily Physical activities	Fitness	**66.p3.** Structured Fitness Opportunities- Physical Activity Breaks **67.p2.** Exterior Active Design- Pedestrian Promotion **67.p3.** Exterior Active Design- Neighborhood Connectivity **68.p3.** Physical Activity Spaces- Physical Activity Spaces for Schools
Thermal Comfort	Comfort	**76.p1.** Thermal comfort - Ventilated thermal environment **76.p2.** Thermal comfort - Natural thermal Adaptation **83.p2.** Radiant Thermal Comfort- Offices And Other Regularly Occupied Spaces
Healthful food	Nourishment	**P4.p1.** Impact Reducing Flooring- Floor Construction **38.p1.** Fruits And Vegetables - Fruit And Vegetable Variety **39.p4.** Processed Foods- Beverages for Secondary School and Adult Education **39.p6.** Processed Foods- Ingredients Restrictions for Schools **44.p1.** Nutritional Information - Detailed Nutritional Information
Acoustic performance	Comfort	**74.p4.** Exterior noise intrusion - Sound Pressure Level in Schools **75.p1.** Internally generated noise - Acoustic planning **75.p2.** Internally generated noise - Mechanical equipment sound levels **75.p6.** Internally generated noise – Noise Criteria in Schools **81.p1.** Sound barriers - Wall construction Specification **78.p2.** Reverberation time - Reverberation Time for Learning Spaces **80.p3.** Sound Reducing Surfaces- School Ceilings
Outdoor air quality	Air	**02.p3.** Smoking ban - Smoke -Free Campus
Visual comfort	Light	**56.p2.** Solar glare control – Daylight management **60.p1.** Automated shading and dimming controls- Automated sunlight control **63.p1.** Daylighting fenestration - Window sizes for working and learning spaces **63.p2.** Daylighting fenestration – Window Transmittance In Working And Learning Areas **61.p2.** Right to light – Window access for working and learning spaces **53.p5.** Visual lighting design –Visual Acuity for Learning **54.p4.** Circadian Lighting Design- Melanopic Light Intensity in Learning Areas **55.p2.** Electric lighting glare control – Glare minimization **57.p1.** Low-glare workstation design – Glare avoidance **58.p1.** Color quality – Color rendering index **59.p1.** Surface design – Working and learning area surface reflectivity
Transportation	Fitness	**69.p3.** Active Transportation Support- Bicycle Storage Facilities for Schools
Indoor Air quality	Air	**16.p1.** Humidity Control- Relative Humidity **11.p1.** Fundamental material safety - Asbestos and lead restriction **23.p2.** Advanced Air Purification - Air Sanitization **13.p1.** Air flush – Air flush **02.p1.** Smoking ban - Indoor smoking ban **05.p2.** Air filtration- Particle filtration **07.p2.** Construction pollution management- Filter replacement **19.p1.** Operable windows - Full control
Water quality	Water	**37.p2.** Drinking water promotion - Drinking water Access **37.p1.** Drinking water promotion - Drinking Water Taste Properties **37.p4.** Drinking water promotion -Outdoor Drinking Water Access

Since the case study was an interior part of a building, some of the indicators that were related to various wellbeing aspects like outdoor air quality, daily physical activity, sustainable transportation, healthful food, water quality, and accessibility have been discarded. So, those indicators which were related to light and indoor air quality have kept into the list. The total number of indicators released from 47 to 20 indicators classifying into two categories; Air and Light. Table 2 shows the 20 number of indicators that have been kept according to their applicability to the case study. 8 indicators are related to the Air category and 12 indicators belong to the Light category.

Table 2. List of indicators applicable to the case study

Category	Indicators
Air	**16.p1.** Humidity Control- Relative Humidity
	11.p1. Fundamental material safety - Asbestos and lead restriction
	23.p2. Advanced Air Purification - Air Sanitization
	13.p1. Air flush – Air flush
	02.p1. Smoking ban - Indoor smoking ban
	05.p2. Air filtration- Particle filtration
	07.p2. Construction pollution management- Filter replacement
	19.p1. Operable windows - Full control
Light	**60.p1.** Automated shading and dimming controls- Automated sunlight control
	63.p1. Daylighting fenestration- Window sizes for working and learning spaces
	61.p2. Right to light- Window access for working and learning spaces
	55.p2. Electric lighting glare control - Glare minimization
	53.p5. Visual lighting design- Visual Acuity for Learning
	57.p1. Low-glare workstation design- glare avoidance
	58.p1. Color quality- Color rendering index
	62.p1. Daylight modeling- Healthy sunlight exposure
	59.p1. Surface design- Working and learning area surface reflectivity
	63.p2. Daylighting fenestration- Window Transmittance in Working and Learning Areas
	54.p4. Circadian Lighting Design- Melanopic Light Intensity in Learning Areas
	56.p2. Solar glare control- Daylight management

The final selection procedure is done through a voting process. The goal of the voting process is to select the most important indicators contributing to the health of occupants according to the experts' opinion. The votes are collected by an online Questionnaire classified into two categories; Air and Light. The number of 80 experts are from the Energy Department of Politecnico di Torino. During the voting process, each indicator takes a rate from 0 to 4 (0= not important 4= very important) by the relevant experts in the field according to the understandability, measurability, and relevancy of the indicators to the students' health. Besides, if participants do not have information about an indicator, they could write DK (Does not know) while filling the questionnaire forms. To clarify more, the rates given to the indicators are from 0 to 4 in each column; understandable, measurable and relevant. Finally, each indicator takes a total rate by summing up the three columns. Table 3 and 4 indicates the results of the voting process done by relevant experts. Each table contains the ranking list of indicators categorizing in the Air and Light category. To explain more, for the calculation process, it has decided to use a formula [12] and select the indicators following the calculation method as described below; The average rate (X) of indicators calculated by summing up the total rates of indicators (Q) and dividing it to the total number of indicators (Z). In this way, the indicators which have total rates (Y) more than the average rate (X) in each category are selected.

$$\frac{Q}{Z} = X \quad \longrightarrow \quad \text{If } Y > X \quad \longrightarrow \quad \text{Select the indicator}$$

Total vote of all the indicators = Q

Total vote of each indicator = Y

Average vote of indicators = X

Total number of indicators = Z

Source: Dr. Drona Rasali, Process and outcome report.

Table 3. List of indicator's rankings results related to the Air category

Indicator	Relevant	Understandable	Measurable	Total Rate
16.p1. Humidity Control- Relative Humidity	130	125	137	392
11.p1. Fundamental material safety - Asbestos and lead restriction	131	113	86	330
23.p2. Advanced Air Purification - Air Sanitization	140	138	106	384
13.p1. Air flush - Air flush	104	90	63	257
02.p1. Smoking ban - Indoor smoking ban	145	150	105	400
05.p2. Air filtration - Particle filtration	132	127	106	365
07.p2. Construction pollution management- Filter replacement	126	116	96	338
19.p1. Operable windows - Full control	133	128	78	339
TOTAL Average				350.62

Table 4. List of indicator's rankings result related to the Light category

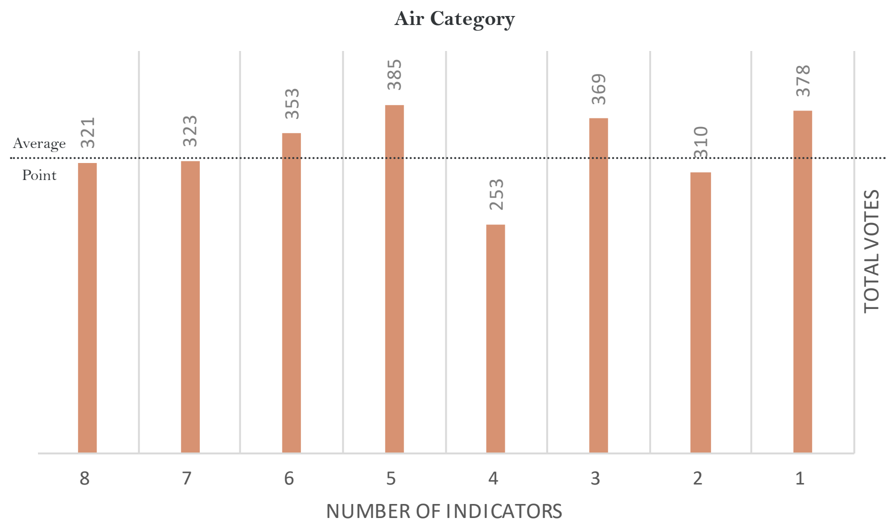
Indicator	Relevant	Understandable	Measurable	Total Rate
60.p1. Automated shading and dimming controls- Automated sunlight control	139	127	118	384
63.p1. Daylighting fenestration- Window sizes for working and learning spaces	137	131	112	380
61.p2. Right to light- Window access for working and learning spaces	128	124	98	350
55.p2. Electric lighting glare control - Glare minimization	120	117	101	338
53.p5. Visual lighting design- Visual Acuity for Learning	129	115	99	343
57.p1. Low-glare workstation design- glare avoidance	142	135	95	372
58.p1. Color quality- Color rendering index	100	102	83	285
62.p1. Daylight modeling- Healthy sunlight exposure	115	107	75	297
59.p1. Surface design- Working and learning area surface reflectivity	105	102	78	285
63.p2. Daylighting fenestration- Window Transmittance in Working and Learning Areas	123	113	100	336
54.p4. Circadian Lighting Design- Melanopic Light Intensity in Learning Areas	93	83	68	244
56.p2. Solar glare control- Daylight management	131	126	99	356
TOTAL Average				330.83

The results of votes show that on-campus level, important rated indicators in the air category are **16.p1.** relative humidity, **23.p2.** Advanced Air Purification, **02.p1.** The smoking ban, and **05.p2.** Air filtration. Also, in the Light category, the highest-ranked indicators are **60.p1.** Automated shading and dimming controls, **63.p1.p2** Daylighting fenestration, **61.p2.** Right to light, **55.p2.** Electric lighting glare control, **53.p5.** Visual lighting design, **57.p1.** Low-glare workstation design, and **56.p2.** Solar glare control. Therefore, the final list of indicators consists of 12 indicators in the light and air categories. Four indicators are belonged to the Air category (**16.p1, 23.p2, 02.p1** and **05.p2**) and eight indicators are related to the light category (**60.p1, 63.p1.p2, 61.p2, 55.p2, 53.p5, 57.p1, 56.p2**). Table 5 indicates the total votes of each indicator divided into the number of experts (40 persons for each category; air and light) who participated in the questionnaire part of the research. After the division process, each indicator takes a rate between 0 to 4 and the other calculation process is like the previous part (see Table 3 and Table 4). There is not any difference between the results of Tables 3, 4 and 5. The aim was to show the results of the research in two ways. Table 3 and 4 show the calculation of the total rates dividing to the number of indicators while Table 5 indicates the calculation of the total rates dividing to the number of persons who have completed the Questionnaire forms. In this way, the votes would be more similar to the actual rates given by participants and the importance of each indicator will be more clear. Also, identifying more important indicators will be easier and more practical. For example, indicator "relative humidity" with a rate of 3.26 over 4 is an important indicator according to the expert opinions and it has a stronger impact on the student's health, while indicator "Fundamental material safety" with a rate of 2.75 over 4 is less important than relative humidity indicator. In this case, more attention should be on the relative humidity indicator because it affects more on the health of students. At the end of this stage, the number of 12 indicators were identified as the most important indicators according to the health of students. So, in this part, the first question got an answer; " what are the most important indicators contributing to the student's health ?"

Table 5. List of winner indicators related to the Air and Light category

Category	Indicators	Rates from 0-4	Average rate	Winners
Air	**16.p1.** Humidity Control- Relative Humidity	3.26	23.37/8= 2.92	●
	11.p1. Fundamental material safety - Asbestos and lead restriction	2.75		
	23.p2. Advanced Air Purification - Air Sanitization	3.20		●
	13.p1. Air flush – Air flush	2.14		
	02.p1. Smoking ban - Indoor smoking ban	3.33		●
	05.p2. Air filtration- Particle filtration	3.04		●
	07.p2. Construction pollution management- Filter replacement	2.81		
	19.p1. Operable windows - Full control	2.82		
Light	**60.p1.** Automated shading and dimming controls- Automated sunlight control	3.20	33.08 /12=2.75	●
	63.p1. Daylighting fenestration- Window sizes for working and learning spaces	3.16		●
	63.p2. Right to light- Window access for working and learning spaces	2.91		●
	55.p2. Electric lighting glare control - Glare minimization	2.81		●
	53.p5. Visual lighting design- Visual Acuity for Learning	2.85		●
	57.p1. Low-glare workstation design- glare avoidance	3.10		●
	58.p1. Color quality- Color rendering index	2.37		
	62.p1. Daylight modeling- Healthy sunlight exposure	2.47		
	59.p1. Surface design- Working and learning area surface reflectivity	2.37		
	63.p2. Daylighting fenestration- Window Transmittance in Working and Learning Areas	2.80		●
	54.p4. Circadian Lighting Design- Melanopic Light Intensity in Learning Areas	2.03		
	56.p2. Solar glare control- Daylight management	2.96		●

The charts below show the indicator's total votes and the average rate. Those indicators with total rates more than the average rate are selected.



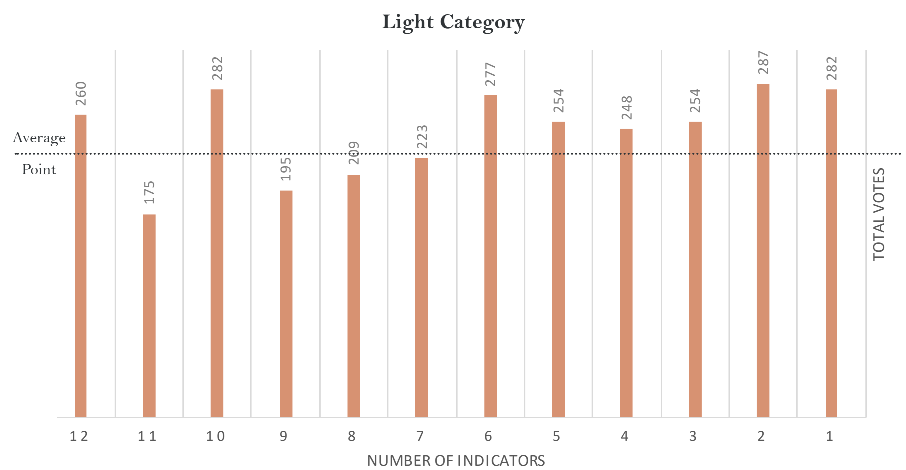


Figure 22. Chart of the indicator's rates

Checking the data availability of indicators for applying on the case study which is classroom 1 at Politecnico di Torino, the number of indicators reduced to 7. According to the data available for each indicator, and considering the case study, the number of indicators in the air category has discarded to 3 indicators; **16.p1.** Humidity Control- Relative Humidity, **02.p1.** Smoking ban - Indoor smoking ban and **05.p2.** Air filtration- Particle filtration. On the other side, only 4 indicators in the light category such as **63.p1.** Daylighting fenestration- Window sizes for working and learning spaces, **61.p2.** Right to light- Window access for working and learning spaces, **63.p2.** Daylighting fenestration- Window Transmittance in Working and Learning Areas and **56.p2.** Solar glare control – Daylight management have been considered before on the case study and the data was available for them. Therefore, it is decided to focus on two categories with 7 indicators for the further steps of the research. All the data were collected from the Data lab and Edilog Area of Politecnico di Torino. Table 6 shows the list of indicators with the data availability for the classroom 1 in Corso Duca Degli Abruzzi, Politecnico di Torino, Italy.

Table 6. List of indicators with data availability

Category	Indicators	Data availability
Air	**16.p1.** Humidity Control- Relative Humidity	●
	02.p1. Smoking ban - Indoor smoking ban	●
	05.p2. Air filtration- Particle filtration	●
Light	**63.p1.** Daylighting fenestration- Window sizes for working and learning spaces	●
	61.p2. Right to light- Window access for working and learning spaces	●
	63.p2. Daylighting fenestration- Window Transmittance in Working and Learning Areas	●
	56.p2. Solar glare control – Daylight management	●

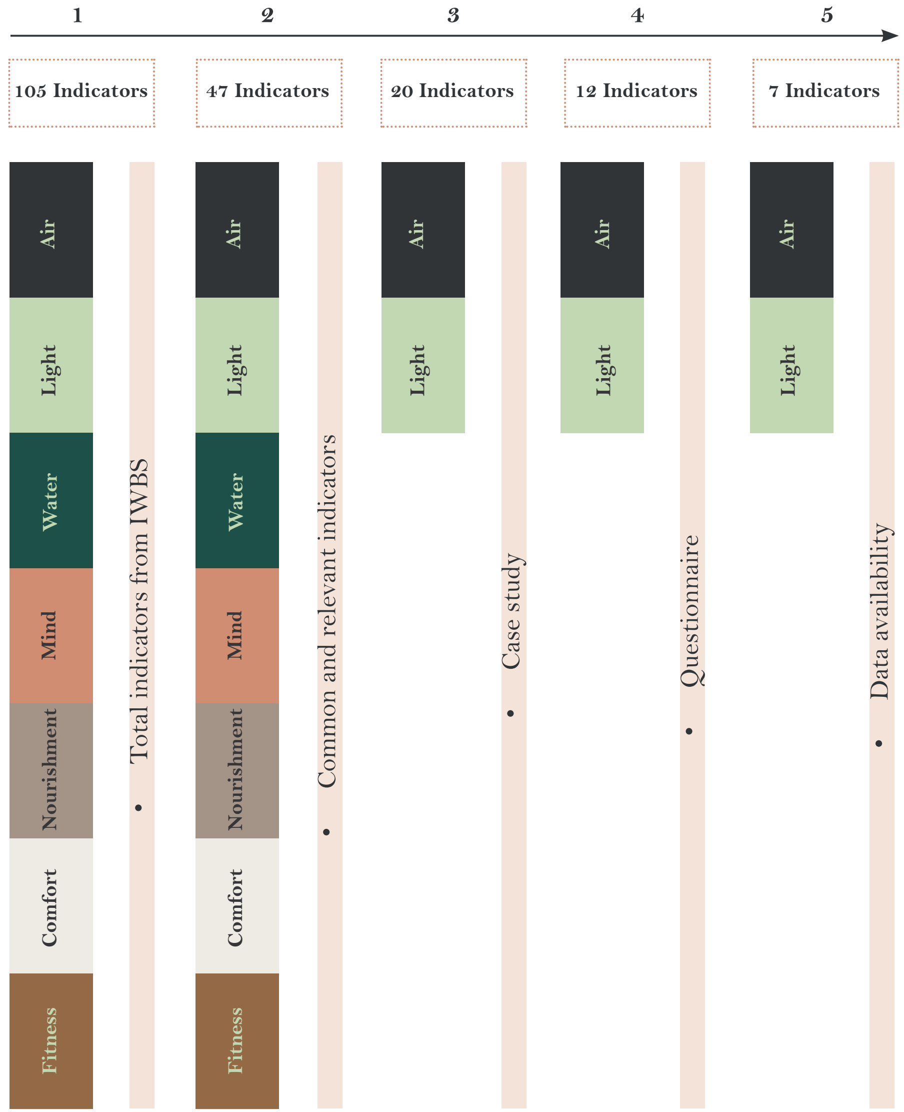


Figure 23. Summarization of indicators selection stages

4.2 Impact Assessment

In this part, the focus of study is on those indicators selected in the previous part. To review the last steps done;

1. By comparing three protocols and their indicators, the number of 47 indicators are selected from IWBS assessment tool.
2. According to the case study which was an interior part of the building, the list of indicators categorizing into two parts of air and light released to 20.
3. Through a voting process and an online questionnaire,12 indicators are selected by the relevant experts in the field of energy.
4. Considering the data availability of the indicators the number of indicators released to seven.

At this step, the impact of the final selected indicators is assessed. To evaluate the indicators on the case study, the analysis is done based on different criteria as listed below:

1. Objective of indicators
2. Description of indicators
3. Unit of indictors
4. Assessment method; Letter of assurance, Annotated documents, On-site assessment
5. Type of calculation method; quantitative, qualitative
6. Availability of data source
7. Easiness of data access for the case study

To explain more, the main objective of each indicator is defined by a brief explanation and following the protocol description, their thresholds are outlined. The unit of measurement of indicators is important because they are recognized and measured by their units like percentage, number, m^2, etc. In addition, the assessment method of indicators may occured by using the annotated documents. For example, in this case some indicators assessed by the architectural drawings provided from Edilog Area of Polito campus. Some of them are assessed by visual inspection and the others use the letters

of assurance which can be declared by an architect. The method of calculation of each indicator could be quantitative which requires special measurements and also they may be qualitative which does not need mathematical calculations and they could be observed by visual inspection. The accessibility to the data for indicators could be variable from very easy to very difficult depending on the different situations. Table 7 summarized the overall impact assessment of the final list of selected indicators. According to what can be seen from the table, each row belongs to an indicator classified into seven parts such as objective, description, unit, assessment method, type, data source and easiness of data access. For example, indicator " Relative humidity" in the first row intend to limit the growth of pathogens, reduce off-gassing, and maintain thermal comfort by providing the appropriate level of humidity. This indicator requires one of the parts to be met; "a. ventilation system with the capability to maintain relative humidity between 30% to 50% at all times by adding or removing moisture from the air and b. Modeled humidity levels in the space are within 30% to 50% for at least 95% of all business hours of the year". The unit of this indicator is percentage and the use of annotated documents like existing data in the data lab of Polito is recommended to be assessed. It is a quantitative indicator because some calculations are needed for the assessment of this indicator. Also, the assessment of these kind indicators is not easy and they should be assessed by the relevant experts and special software. The indicator "Smoking ban" with the objective of minimizing occupant exposure to second-hand smoke, and reducing smoke pollution is a qualitative indicator and it can be assessed by an on-site assessment. This indicator must meet the protocol target; smoking and the use of e-cigarettes should be prohibited inside the project.The data accessibility for this indicator is very easy because all the policy documents and rules have published on the internet. These two examples could help to understand better all the other indicators and their key items which are described at the Table 7. This Table explains about all the seven indicators which were chosen in the last part as the final selected ones and an overall skim for the assessment of those 7 indicators is presented in a clear way.

Table 7. Summarization of overall assessment of the selected indicators

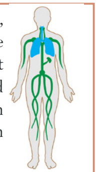
Criteria	Indicator	Objective	Description	Unit	Assessment method			Type		Data source	Easiness of data access
					Letter of assurance	Annotated documents	On-site assessment	Quantitative	Qualitative		
Air	**16.p1.** Humidity Control- Relative Humidity	To limit the growth of pathogens, reduce off-gassing, and maintain thermal comfort by providing the appropriate level of humidity.	At least one of the following is required: a. A ventilation system with the capability to maintain relative humidity between 30% to 50% at all times by adding or removing moisture from the air. b. Modeled humidity levels in the space are within 30% to 50% for at least 95% of all business hours of the year. Buildings in climates with narrow humidity ranges are encouraged to pursue this option.	%		Calculations & Measurement		●		Polito Data Lab	Difficult
	02.p1. Smoking ban - Indoor smoking ban	To deter smoking, minimize occupant exposure to second hand smoke, and reduce smoke pollution.	Building policy or local code reflects the following: a. Smoking and the use of e-cigarettes is prohibited inside the project	–		Policy Document			●	Internet	Easy
	05.p2. Air filtration – Particle filtration	To remove indoor and outdoor airborne contaminants through air filtration.	One of the following requirements is met: a. MERV 13 (or higher) media filters are used in the ventilation system to filter outdoor air. b. Project demonstrates that for 95% of all hours in a calendar year, ambient outdoor PM10 and PM2.5 levels measured within 1.6 km [1 mi] of the building are below the limits set in the WELL Air Quality Standards Feature.	%		Calculations		●		ARPA Piemonte	Difficult
Light	**63.p1.** Daylighting fenestration – Window sizes for working and learning spaces	To optimize occupant exposure to daylight and limit glare through enhanced fenestration parameters.	The following conditions are met on facades along regularly occupied spaces: a. Window-wall ratio as measured on external elevations is between 20% and 60%. Percentages greater than 40% require external shading or adjustable opacity glazing to control unwanted heat gain and glare. b. Between 40% and 60% of window area is at least 2.1 m above the floor.	%		Architectural Drawing	Visual Inspection	●	●	Area Edilog	Medium
	63.p2. Daylighting fenestration – Window Transmittance In Working And Learning Areas	To optimize occupant exposure to daylight and limit glare through enhanced fenestration parameters.	The following visible transmittance (VT) conditions are met for all non-decorative glazing: a. All glazing located higher than 2.1 m [7 ft] from the floor has VT of 60% or more. b. All glazing (excluding skylights) located 2.1 m [7 ft] or lower from the floor has VT of 50% or more.	nm	Architect	Architectural Drawing			●	Technical office at Polito	Difficult
	61.p2. Right to light – Window access for working &learning spaces	To promote exposure to daylight and views of varying distances by limiting the distance workstations can be from a window or atrium.	The following conditions are met: a. 75% of all workstations are within 7.5 m of an atrium or a window with views to the exterior. b. 95% of all workstations are within 12.5 m of an atrium or a window with views to the exterior.	m		Architectural Drawing	Visual Inspection	●	●	Area Edilog	Medium
	56.p2. Solar glare control – Daylight management	To avoid glare from the sun by blocking or reflecting direct sunlight away from occupants.	At least one of the following is required for all glazing greater than 2.1 m above the floor in regularly occupied spaces (excluding lobbies): a. Interior window shading or blinds that are controllable by the occupants or set to automatically prevent glare. b. External shading systems that are set to automatically prevent glare. c. Interior light shelves to reflect sunlight toward the ceiling. d. A film of micro-mirrors on the window that reflects sunlight toward the ceiling. e. Variable opacity glazing, such as electrochromic glass, which can reduce transmissivity by 90% or more.	–	Architect	Architectural Drawing	Visual Inspection	●	●	Area Edilog	Medium

4.2.1 Indicator's Data verification

This part is allocated to the indicator's data verification according to the protocol requirements. The data verification for the final selected indicators is investigated to see if indicators meet the protocol targets or not. To explain more, each indicator is surveyed and measured by using the existing data from the data lab and Edilog Area at Politecnico di Torino to see whether it meets the target of the protocol or not. It is tried to assess the seven indicators by using the existing data to investigate the role of each indicator affecting the student's health in the classroom. By verifying the data, it is possible to assess the indoor quality of the classroom and to understand the problems which are inside. These assessments help to solve the indoor problems and, at the same time, it helps to promote the students' health. In the section ahead, it is attempted to fully describe all the indicators that have been finalized in the last part and their relationship to individual health issues are examined. To clarify more, it is necessary to discover what effects each indicator has on student's health, for example, if the level of the indicator "relative humidity", is lower than a certain level, it can cause dryness and irritation of the skin, eyes, throat and mucous membranes, and if it is more than a certain level, can cause respiratory irritation and allergies for people. Therefore, it is important to pay attention to the amount of humidity level at buildings and to not allow it to go above or below the specified limit and try to not to endanger the health of the people in the area. As mentioned in the tables below, the protocol threshold is specified for each indicator and it is enough to evaluate the indicator on the case study (classroom1 at Politecnico Di Torino) and compare it with the protocol threshold and state the result in the final section of the table. After announcing the results and comparing them with the Protocol target, it will be possible to determine how each indicator behaves in the case study. Does this indicator match the protocol target? Failure to meet the target of the Protocol indicates a deficiency in the case study and the inadequacy of the indicator disrupts the students. As these indicators are considered to be very important by relevant experts, they need to be

addressed and provide solutions to improve students' health. The upcoming part allocated to the data verification of each indicator. Tables 8 to 15 are devoted to evaluating the indicators and they are thoroughly examined on the studied case study and the results of the survey are fully described. Besides, Table 8 to 10 are related to the Air category indicators and Table 11 to 15 belong to the Light category indicators. Each table belongs to an indicator and it is divided into eight parts which are category, indicator's name, objective, background, protocol target, assessment methodology, calculation process, and result. The indicators are assessed according to their applicability to the case study. For example, the assessment methodology for the relative humidity indicator is done by some calculations. The measures are obtained from the software that checks the relative humidity at different times which is captured by the machine. For the calculation process there is an architecture for data acquisition that starts from probes in the field, then having analog to digital converter (Moxa 1240) then an Ethernet IP connection with a variant of Modbus protocol over IP, next a script written by data manager in a language called "Perl", there is a storage, provided by a relations database based on Microsoft SQL Server. The reference period is the year 2018 in this research project and all the data calculation for checking the relative humidity refers to 2018 for all business hours. The result of assessment for this indicator is negative and this indicator does not follow the protocol requirements. It can be concluded that this indicator is not well organized in the classroom 1 at Politecnico Di Torino and is already weak. So, it is necessary to improve this indicator in the classroom and help students to feel better during the time. The other indicators are assessed like the above-mentioned example and the result of their assessment process are described in the tables below.

Table 8. Characteristics of Relative humidity indicator

Air Category	
Indicator Name	**16.p1.** Humidity Control- Relative Humidity
Objective	To limit the growth of pathogens, reduce off-gassing, and maintain thermal comfort by providing the appropriate level of humidity. [75]
Background	Extremely low humidity can lead to dryness and irritation of the skin, eyes, throat and mucous membranes. Conversely, high humidity may promote the accumulation and growth of microbial pathogens, including bacteria, dust mites and mold, which can lead to odors and cause respiratory irritation and allergies in sensitive individuals. Additionally, higher humidity levels can lead to increased off-gassing: an increase in relative humidity of 35% can increase the emissions of formaldehyde by a factor of 1.8–2.6. [75] 
Protocol Target	At least one of the following is required: a. A ventilation system with the capability to maintain relative humidity between 30% to 50% at all times by adding or removing moisture from the air. b. Modeled humidity levels in the space are within 30% to 50% for at least 95% of all business hours of the year. Buildings in climates with narrow humidity ranges are encouraged to pursue this option. [75]
Assessment methodology	The indicator assessed by calculations. The measures obtained are not from the software that controls the HVAC plant and it is a different network of probes, sensors, data log, software and so on. This software checks the relative humidity at different time which is captured by the machine.
Calculating Process	There is no single "software" that gives the measurements. There is an architecture for data acquisition that starts from probes in the field, then having analog to digital converted (Moxa 1240) then an Ethernet IP connection with a variant of Modbus protocol over IP, next a script written by data manager in a language called "Perl", then there is a storage, provided by a relations database based on Microsoft Sql Server. The reference period is year 2018 in this research project and all the data calculation for checking the relative humidity refers to 2018 at business hours.
Result	After the HR checking process, it has captured that HR is not between 30% and 50% of all business hours of the year. Most of the time, the results of HR check is outside the 30-50 range, and is often above 50% or below 30%.The problem is that because there is no HR control and there is no device to control the relative humidity, so the relative humidity is out of control. The Excel file listed in Appendix D is the result of a query ran over the database. UTA1 does not control the HR, it is an old plant, dating bank to 1990s. So the values in the excel files are the result of many things but NOT HR control. Therefore, when students are in the classroom and the relative humidity level is not good, they will suffer during the time. In this case, it can be concluded that the relative humidity level in the classroom 1 at Polito is not in equilibrium and should be upgraded. This indicator does not meet the target of the protocol.

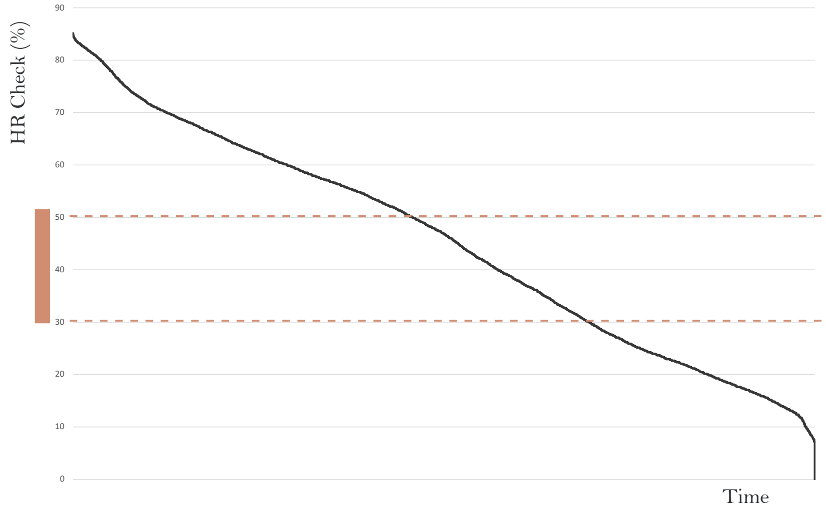


Figure 24. Impact assessment of relative humidity indicator

This is a very simple graph just to show how the values are arranged. The two orange lines are the limits in which the HR must be measured during business hours. The fact is that there is no matching because the machine has no device aimed to control HR. Relative humidity is measured because there is a probe in the upstream duct and it is known that in a single particular moment the value of HR is 72% but the value of 72 is not a result of a specific activity of the machine. It is a consequence of the people are there, how the outside air is if the air is heated or cooled by people before sending it inside. So, the plant of ventilation and acclimatization of classroom 1 has no device to control HR. This is one of the reason that the ventilation unit of classroom 1 is obsolete and must be changed with a new plant. In 1983 there was no acclimatization and no cooling system, it was very hot so during the summer and there was just some ventilation. Then in the early 1990s, a new machine was installed. It was one of the newest machines available on the market. Regarding these graphs, the plant that is depicted in the picture has no control of HR. It is the answer to the fact that the very few hours match the requirements. As can be seen from the line graph, most of the times, HR is not in the required range.

This section summarizes the HVAC system used in classroom 1 at Polito campus. This is the machine that control the ventilation, cooling in the summer and warming during the winter. The machine does not control relative humidity.

HVAC system description:

- All air system
- About 10000 m3/h of supply air
- 8000 m3/h return air
- 2000 m3/h get lost: overpressure
- Supply air fan ~3 kW; return air fan ~1.5 kW
- No inverter, fixed speed fans: as the filter gets clogged the energy consumption gets lower

The ceiling in the picture is the floor of the classroom 1.

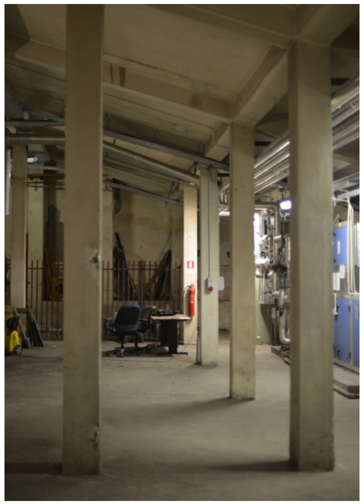


Figure 25. HVAC system serving at classroom 1, Politecnico di Torino
Source: Photographs by Dr. Giovanni Carioni, Polito Data Lab, October 2018

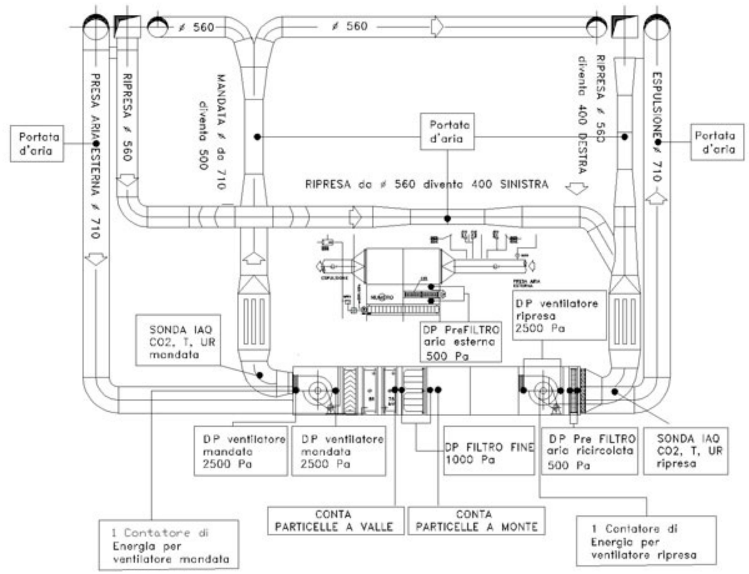


Figure 26. Schematic plant of UTA at classroom 1, Politecnico di Torino
Source: Polito Data Lab, October 2018

UTA is a device used to regulate and circulate air as part of the HVAC system.

Operating modes:

- 100% outdoor air
- Partial recirculation
- Total recirculation
- Control logic of dampers position not available
- By fall 2016 we should be able to read some more parameters from Design via a Modbus interface (i.e. damper position)

Data history:

- Not all measurements available since the beginning of the project (2011)
- Outdoor and exhaust airflow rate added during 2013
- Thermal energy measure added during 2012
- Air temperature in proximity of fine filter added during 2015

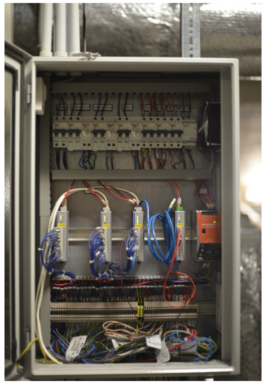
Data acquisition:

- 4 **Moxa ioLogik E1240**, Ethernet remote I/O with 2-port Ethernet switch, 8 Ais for probes with analog output (0-10V, 4-20 mA)
- 1 **GH Solutions M500** data logger for electric energy meters (gateway from Modbus to Ethernet)
- 2 **Moxa NPort 5001** serial to Ethernet converter for connecting the two particles counters

The detail related to how the data is taken from the machine.

Cabinet containing data logger

and ABB meters (hidden)



Cabinet containing the

4 Moxa ioLogik E1240

AD converters

GH Solutions M500 data logger

Figure 27. HVAC monitoring systems at classroom 1, Politecnico di Torino
Source: Photographs by Dr. Giovanni Carioni, Polito Data Lab, October 2018

The activity about observing HVAC and the details of the system works in classroom1.

Time interval of data acquisition:

- Selecting the time duration from the start of the project: every 15 minutes, 24 hours a day, 7 days a week
- This selection is stable for electrical energy measurement
- More than sufficient to explain the system during its operations (i.e. years)
- No professional software engineers in the first project stage, need to analyze experimental data using MS Excel.

Software for data acquisition:

- Two common SCADA applications written in Movicon (similar to VBasic)
- Analog investigations and electric energy, via MODBUS/TCP
- Digital data from components counters via MODBUS/RTU
- In October 2015, the application #1 has been prohibited in favor of a more effective and simple Perl script and free command-line system to seek Modbus devices (MODPOLL. EXE); it is launched on a virtual machine which is more available.
- We are considering prohibiting application #2; Because of need to read from but also to write to Modbus registers to manage the optical particle counters, it probably is a bit difficult.

Data storage:

- In 2011, in the first implementation, every 15 minutes, one sample read and its value saved in the database.
- That specific value was THE measured value for that full-time interval
- That particular value was as the same as THE measured value for that full-time duration
- Starting from October 2015, in the first weeks, more samples every 15 minutes: 90 (i.e. one every 10 seconds), then 30 (i.e. one every 30 seconds) after prohibiting Movicon app,
- At first, each sample is stored in the text file, one file takes15 minutes
- Afterward, data is saved in an MS SQL Server 2012 relational database: ~ 300 GB of disk space shared with other data acquisition systems

Table 9. Characteristics of Smoking ban indicator

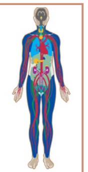
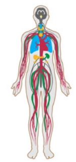
Air Category	
Indicator Name →	**02.p1.** Smoking ban - Indoor smoking ban
Objective	To deter smoking, minimize occupant exposure to second hand smoke, and reduce smoke pollution.[75]
Background	Over 42 million adults in the U.S. and over a billion individuals worldwide are cigarette smokers. In the U.S. smoking tobacco is related to over 400,000 premature annual deaths. Furthermore, the average life expectancy of a smoker is 10 years less than that of a non-smoker. In addition to nicotine, cigarettes contain about 600 ingredients that form over 7,000 compounds when burned, of which at least 69 are known to be carcinogenic. Secondhand smoke exposes non-smokers to the same toxins, increasing the number of people subject to health risks from smoking. [75] 
Protocol Target	Building policy or local code reflects the following: a. Smoking and the use of e-cigarettes is prohibited inside the project. [75]
Assessment methodology	The indicator assessed on-site by visual inspection.
Calculating Process	This indicator is qualitative and it does not need special calculations.
Result	In 1972, the ban of advertisements related to smokers' products was proposed in Italy, on the evidence of the EEC. On 11th of November 1975 the lawn. 584 which abandons smoking on public transport, except special transportations reserved for smokers, and in some public places such as hospitals, cinemas, theaters, museums, universities, and libraries. In 1986 the then Minister of Health Constant Degan presented a bill which tried to expand these prohibitions also to restaurants and workplaces. This caused much contention, this project was finished very soon. Beginning in 1991, for the first time in Italy, large written letters appear on smoke products: "Smoking is harmful". [Source: quotidiano la Stampa del 15/12/1995, page:17]. 16th of January 2003, in Italy the lawn. 3 art. 51 established that "it is forbidden to smoke in enclosed spaces, except for private ones not open to users or the public;" except special smoking rooms which food can also be served in. The anti-smoking law, which is currently in force, is also called the Sirchia law, with strong requests by the then Minister of Health of the Berlusconi government Girolamo Sirchia entered into force on 10th of January 2005. According to a sentence from TAR of Lazio on the 1st of August 2005, confirmed by the Council of State on 7th of October 2009, sanctions are no longer considered for the manager who does not report offending customers to the public force. In 2013, an amendment also adds the ban to outdoor areas related to educational institutions. [Source: https://it.wikipedia.org/wiki/Legge_antifumo#cite_note-1]. After visiting the classroom and checking the policy documents and laws which were published for public places like Universities in Italy, it has captured that smoking is forbidden into the classroom 1 of Polito campus. This indicator meets the target.

Table 10. Characteristics of Air filtration indicator

Air Category	
Indicator Name →	**05.p2.** Air filtration- Particle filtration
Objective	To remove indoor and outdoor airborne contaminants through air filtration.[75]
Background	Air quality is subject to variability due to weather, dust, traffic and localized pollutant sources. Seasonal variations in pollen can trigger asthma and allergies in sensitive individuals. Similarly, exposure to high levels of coarse and fine particulate matter introduced from the outside can lead to respiratory irritation and has been associated with increases in lung cancer as well as cardiovascular disease and mortality. Carbon filters are designed to absorb such volatile pollutants and remove the largest particles, while media filters are meant to address smaller particles.[75] 
Protocol Target	One of the following requirements is met: a. MERV 13 (or higher) media filters are used in the ventilation system to filter outdoor air. b. Project demonstrates that for 95% of all hours in a calendar year, ambient outdoor PM10 and PM2.5 levels measured within 1.6 km [1 mi] of the building are below the limits set in the WELL Air Quality Standards Feature.[75]
Assessment methodology	The indicator assessed by measurements and it calculated with special energy software. This software checks all the filters which are located into the ventilation systems of classroom1 at Polito to find Minimum Efficiency Reporting Value (MERV).
Calculating Process	The particle size range [nm] Average minimum PSE designator % Fractional efficiency % The efficiency value for a filter is a pure number, because it is the number of particle downstream after the filter divided for the number of particle upstream before filtering. The formula is: $1- \frac{\text{the number of particle downstream after filtering}}{\text{the number of particle upstream before filtring}} * 100 = X (\%)$
Result	This data is measured by ARPA Piemonte, Italy. They have calculated the MERV classification of the filters placed inside the air handling unit serving Classroom 1. All of them correspond to MERV 15. This indicator meets the Protocol target. Filtering is better than the minimum required.

An air filter's operation is determined by measuring the particle counts upstream and downstream of the air-cleaning device being tested. Particle counts are taken over the range of particle sizes six times, beginning with a clean filter and then after the addition of standard synthetic ASHRAE dust loadings for five additional measurement cycles. An aerosol generator which its performance is like a paint sprayer is used to make a challenge aerosol of known particle size in the air current, and it will produce particles covering the 12 required particle size ranges for the test (Table 11). The aerosol being tested is applied to the test current and particle counts are taken for each of the size data points. The performance of the filter is determined, during the six test cycles (totally 72 value or calculated value) on per size of those twelve particles. The filtration efficiency is stated as a ratio of the downstream-to-upstream particle count for per value or calculated value. The twelve size ranges are located in three larger branches according to the following schedule: ranges 1-4 (or E1, which is 0.3 to 1.0 µm), ranges 5-8 (or E2, which is 1.0 to 3.0 µm), and ranges 9-12 (or E3, which is 3.0 to 10.0 µm). Averaging the Composite Minimum Efficiency for each of these branches will calculate the average Particle Size Efficiency (PSE), and the resulting three percentages (E1, E2, E3) are then used to determine the MERV. [Source: NAFA User's Guide for ANSI/ASHRAE Standard 52.2-2017].

Table 11. Particle size ranges

Range	Size	Group
1	0.3 to 0.4	E1
2	0.4 to 0.55	
3	0.55 to 0.7	
4	0.7 to 1	
5	1 to 1.30	E2
6	1.30 to 1.60	
7	1.60 to 2.20	
8	2.20 to 3.00	
9	3.00 to 4.00	E3
10	4.00 to 5.50	
11	5.50 to 7.00	
12	7.00 to 10.00	

Source: NAFA User's Guide for ANSI/ASHRAE Standard 52.2-2017

The MERV is a single number that is used to simplify the extensive data generated by the test method, along with the air velocity at which the test was performed. MERV is expressed on a 16-point scale and is derived from the PSE for each of the three groups. The average PSE is referenced against the Minimum Efficiency Reporting Value Parameters for each of the three groups (E1, E2, and E3) (see Table 12). The degree of filtration required in educational buildings includes several contributing factors. Such recommendations are given based on the ideal filtration to protect HVAC equipment and improve the education building system health of students and faculty. MERV 13 filters are able to protect HVAC equipment and remove target respirable particulates that could cause disease and should reduce the overall school absenteeism. [Source: NAFA Guide to Air Filtration 4th Edition,2012].

Table 12. Minimum Efficiency Reporting Value (MERV) parameters

MERV Ratings					
MERV Rating	Average Particle Size Efficiency (PSE), microns - % Removal			Typical Controlled Contaminant or Material Sources (ASHRAE 52.2)	Typical Building Applications
	0.3-1.0	1.0-3.0	3.0-10.0		
1-4			<20%	> 10 Microns Textile Fibers Dust Mites, Dust, Pollen	Window AC units Common Residential Minimal Filtration
5			20-35	3.0 to 10.0 Microns Cement Dust, Mold Spores, Dusting Aids	Industrial Workplace Better Residential Commercial
8			>70		
9		<50	>85	1.0 to 3.0 Microns Legionella, Some Auto Emissions, Humidifier Dust	Hospital Laboratories Better Commercial Superior Residential
12		>80	>90		
13	<75	>90	>90	0.3 to 1.0 Microns Bacteria, Droplet Nuclei (sneeze), Most Tobacco Smoke, Insecticide Dust	Educational Buildings Superior Commercial Smoking Lounge Hospital Care General Surgery
16	>95	>95	>90		

Source: Adapted from EPA 2009; originally from ANSI/ASHRAE Standard 52.2-2007

Particle counters are very expensive and measuring these numbers is difficult and very costly. Generally, particle counters are designed to measure the clearness of the air in a cleanroom where there is a very low number of particles. It has been tried to do that in classroom 1 at Polito. But it is forced to work at the upper limit of its capacity to count the particles once a year and to send it to the laboratory to clean, reset and redo the calibration. It's more than a year that the researcher is without counter because they have been put it in the same contamination situation and have different results. If there are nearly zero particles, they must read zero or something very similar, instead, there would be very different results because one of these particle counters has been exposed to a much more contamination situation, than the counter downstream. The age of the device is much higher for the counter upstream than downstream because an optical component is a photodiode that receive the light and counts the shade projected by the particles. So, these optical components have lower quality during lifetime. Practically, measuring is nearly impossible. Therefore, the solution is to ensure that the filters that are used, certified and they have certain efficiency and guaranty. The laboratory specializes in ensuring about filter's behavior. When talking about efficiency, the behavior of the filter in overall behavior are automatically described. Particles upstream and downstream are not counted, upstream and downstream should be counted to calculate the efficiency. Existing particle counters in classroom 1 have six channels that from 0.3 to 1 nm, 1 to 3, 3 are measured to 10, but the counter can count the particles concerning their size within some intervals. So, when it is spoken about efficiency, it is necessary to define the size of the considered particle because some material for filtering can have an efficiency when working with big particles and they can have much lower efficiency when the particles are very small. The particle counters at classroom 1 at Polito, count only in the first channel simply because two other filters work for the biggest particles. Figure 28 shows the physical disposition of filters in classroom 1. Filters have a standard size for putting into the ducts. So, it is necessary to put two filters full size, and then two filters half a size. They are called fine filters because fine is related to the size of the particles so, it is aimed to filter the smallest part.

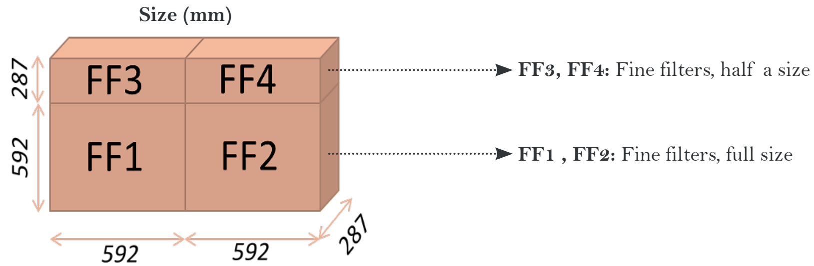


Figure 28. Scheme Of Fine Filters Bank

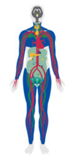
Table 13 shows the result of fractional efficiency data for the classroom 1 at Polito campus. All the filters placed inside the air handling unit serving Classroom 1 correspond to MERV 15 and by this results, it can be confirmed that the filtration is better than the minimum required.

Table 13. Impact assessment of air filtration indicator

Particle size range[nm]			Fine filter #1		Fine filter #2		Fine filters #3 and #4	
Lower limit	Upper limit	Geometric mean	Fractional efficiency [%]	Average minimum PSE [%]	Fractional efficiency [%]	Average minimum PSE designator [%]	Fractional efficiency [%]	Average minimum PSE designator [%]
300	400	346.41	78.73	87.85	80.25	89	78.18	87.06
400	550	469.04	86.36		87.72		85.79	
550	700	620.48	90.89		92.49		90.51	
700	1000	836.66	95.4		95.54		93.75	
1000	1300	1140.18	99.6	97.69	97.18	98.22	96.43	97.10
1300	1600	1442.22	99.6		97.83		96.42	
1600	2200	1876.17	98.32		98.72		97.18	
2200	3000	2569.05	99.40		99.13		98.35	
3000	4000	3464.10	99.60	99.83	99.30	99.60	98.60	99.20
4000	5500	4690.42	99.80		99.50		99.00	
5500	7000	6204.84	99.90		99.70		99.40	
7000	10000	8366.60	100		99.90		99.80	
Minimum Efficiency Reporting Value (MERV)			MERV 15		MERV 15		MERV 15	

*The fractional efficiency values in orange are estimated values and NOT correspond to measured data

Table 14. Characteristics of daylight fenestration- window sizes indicator

Light Category	
Indicator Name	**63.p1.** Daylighting fenestration – Window sizes for working and learning spaces
Objective	To optimize occupant exposure to daylight and limit glare through enhanced fenestration parameters.[75]
Background	Exposure to natural light can improve occupant mood, alertness, and overall health. Ideal lighting involves proper exposure to diffuse daylight, as well as careful design of windows and glazing to avoid excessive glare and heat gain. Windows are therefore a key variable for both ensuring that occupants receive enough light for positive physiological and subjective effects, but also not too much light that causes discomfort or becomes a source of distraction. Balancing energy performance, thermal comfort and access to quality daylight is essential to proper building design. [75] 
Protocol Target	The following conditions are met on facades along regularly occupied spaces: a. The window-wall ratio as measured on external elevations is between 20% and 60%. Percentages greater than 40% require external shading or adjustable opacity glazing to control unwanted heat gain and glare. b. Between 40% and 60% of the window, the area is at least 2.1 m above the floor. [75]
Assessment methodology	The indicator assessed by architectural drawings of classroom such as section, plan, view and an on-site survey. The distance between the windows and floor is measured.
Calculating Process	Using Architectural drawings (DWG) to measure the area of windows rather than the wall. The formula for the Window-wall ratio is: (the area of windows / the area of the walls) *100= Ratio > 40% ⟶ windows need external shadings
Result	Checking of the section and plan of classroom and a survey, it has captured that all the windows are about 3.5 m above than the floor and The window- wall ratio was about 45% and all the windows have external shadings and they control the unwanted heat and glare. So, part a and b are observed and the indicator meet the protocol threshold and it is well established in the classroom. The students never have any problem with daylight.

Wall number 1

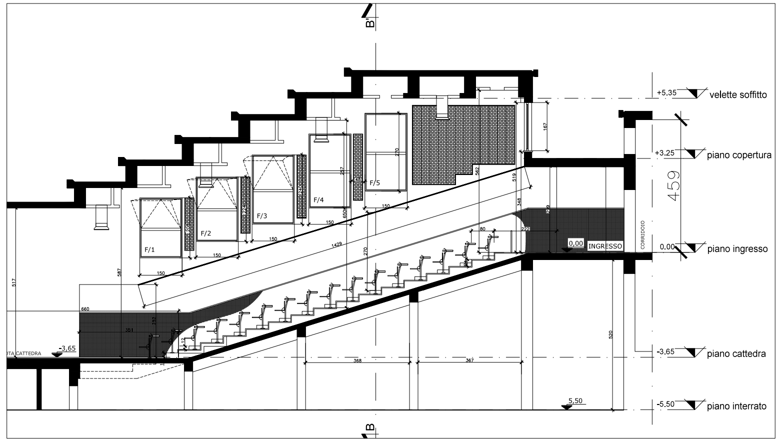


Figure 15. Section of classroom 1, Politecnico di Torino
Source: Area Edilog, Polythechnic University of Turin, October 2019

Wall number 2

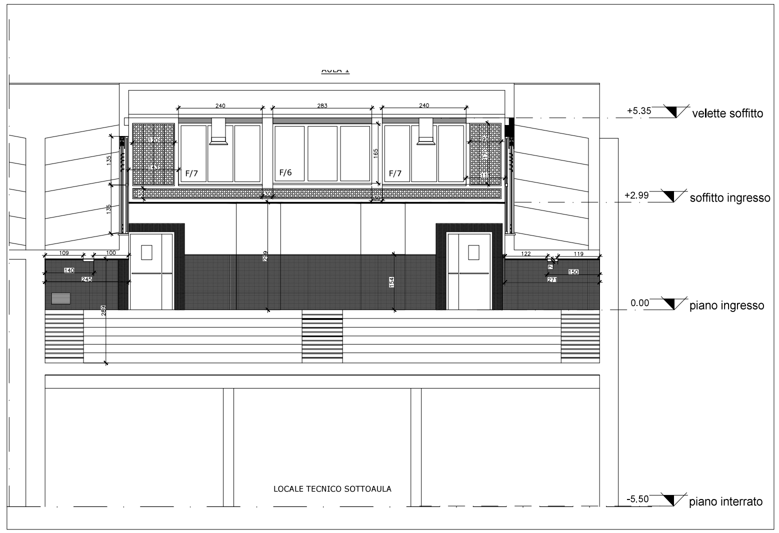


Figure 16. View of classroom 1, Politecnico di Torino
Source: Area Edilog, Polythechnic University of Turin, October 2019

Wall number 1:

(Area windows / Areawall) * 100 =

[(208*150)+ (224*150)+(240*150)+(257*150)+ (270*150)] / 13166.28= 13%

Wall number 2:

(Area windows / Areawall) * 100 =

[(2* (240*165)) + (283*165)]/ 646697= 19%

Total:

(2* Wall number 1 ratio)+ Wall number 2 ratio=

(2* 13%) + 19%= 45%

The classroom has a total of three exterior walls and 13 windows with different types and sizes. The calculations are done by measuring the ratio of the area of the windows on a wall to the total area of that wall and finally, all the ratios are combined. The final ratio of windows to the walls is 45%. This number is between a range of 40% and 60%, and according to the interior pictures of the classroom, it can be seen that all the windows have exterior blinds and they are illuminated to prevent excessive heat and light from entering at certain times of the day.

Figure 29. Interior pictures of classroom1, Politecnico di Torino

Table 15. Characteristics of right to light indicator

Light Category	
Indicator Name	**61.p2.** Right to light- Window access for working and learning spaces
Objective	To promote exposure to daylight and views of varying distances by limiting the distance workstations can be from a window or atrium.[75]
Background	Exposure to adequate levels of sunlight is critical for health and well-being, for effects ranging from visual comfort to potential psychological and neurological gains: there are measurable physiological benefits to receiving the quality of light provided by the sun, as well as positive subjective reports from occupants able to enjoy access to sunlight. Proximity to windows, outdoor views, and daylight in indoor spaces are some of the most sought-after elements of design. As such, buildings should utilize daylight as a primary source of lighting to the greatest extent possible. [75] 
Protocol Target	The following conditions are met: a. 75% of all workstations are within 7.5 m of an atrium or a window with views to the exterior. b. 95% of all workstations are within 12.5 m of an atrium or a window with views to the exterior. [75]
Assessment methodology	The indicator assessed by architectural drawings of the classroom such as floor plan and an on-site survey. The distance between the windows and student desks is measured.
Calculating Process	Using architectural drawings (DWG) to measure the distance between chairs and desks from windows.
Result	Checking of the DWG plan of the classroom and an on-site survey, it has captured that 84% desks are within 7.5m distance from windows and 16% of desks are within 12.5 m distance from desks. But the students could not see the exterior part of the classroom. Because all the windows are above their heads and the classroom plan is a staircase. the windows have been changed 2-3 years ago. The windows are manually opened by the electrical component. The result is that Windows for the corridor are very high and they remain too high and people that live there are not happy with their windows. Considering the cross-section, the windows are more than 3 meters higher than the floor and the students are not allowed to see the outside. On the other hand, there are columns and concrete walls around the exterior walls of the classroom, and the windows only have the function of moving light and there is no visual view of the outside public space. As shown in the pictures below, the windows are above the students' heads and the desks are more than 7.5 meters away from the windows. This indicator does not meet the protocol threshold.

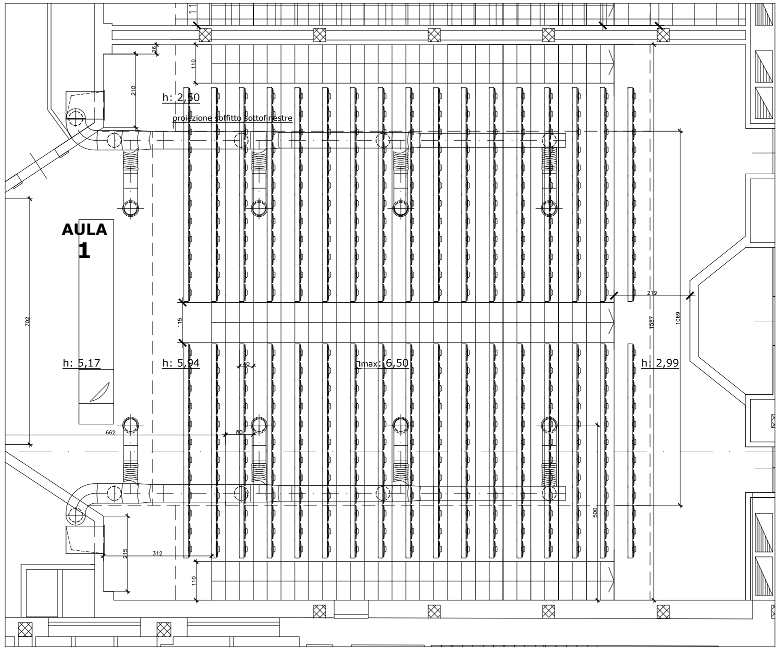


Figure 14. Plan of classroom 1, Politecnico di Torino
Source: Area Edilog, Polythechnic University of Turin, October 2019

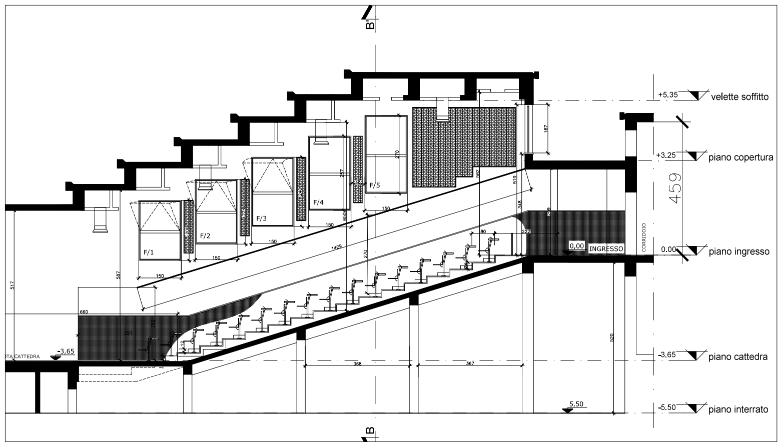


Figure 15. Section of classroom 1, Politecnico di Torino
Source: Source: Area Edilog, Polythechnic University of Turin, October 2019

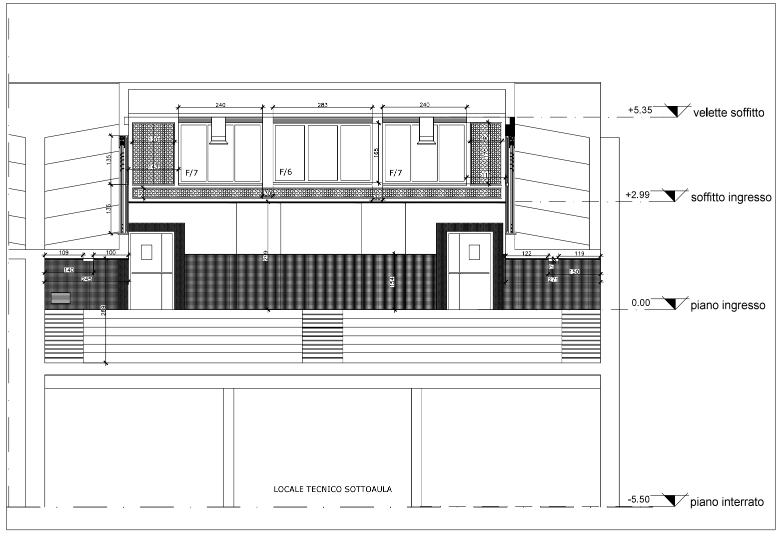


Figure 16. View of classroom 1, Politecnico di Torino
Source: Area Edilog, Polythechnic University of Turin, October 2019

Figure 29. Interior pictures of classroom1, Politecnico di Torino
Source: Photographs by Farzaneh Aliakbari, October 2019

Table 16. Characteristics of daylight fenestration- window transmittance indicator

Light Category	
Indicator Name	**63.p2.** Daylighting fenestration- Window Transmittance in Working and Learning Areas
Objective	To optimize occupant exposure to daylight and limit glare through enhanced fenestration parameters.[75]
Background	Exposure to natural light can improve occupant mood, alertness, and overall health. Ideal lighting involves proper exposure to diffuse daylight, as well as careful design of windows and glazing to avoid excessive glare and heat gain. Windows are therefore a key variable for both ensuring that occupants receive enough light for positive physiological and subjective effects, but also not too much light that causes discomfort or becomes a source of distraction. Balancing energy performance, thermal comfort and access to quality daylight is essential to proper building design. [75] 
Protocol Target	The following visible transmittance (VT) conditions are met for all non-decorative glazing: a. All glazing located higher than 2.1 m from the floor has VT of 60% or more. b. All glazing (excluding skylights) located 2.1 m or lower from the floor has a VT of 50% or more. [75]
Assessment methodology	The indicator assessed by the technical office manager of Polito campus.
Calculating Process	Using the Architectural drawings (section) of the classroom to measure the distance between windows and floors and also checking the existing information for glazing which were used for the windows of classroom1.
Result	After measuring the distance between windows and floor it has captured that the distance is about 3.5 m. By asking from the technical office of Polito, some people ensure that those requirements are matched But people were unable to provide proof of that. They have declared that all the glasses which were used for windows of classroom 1 at Polito campus have visual transmittance of about 60%. Relying on their declaration, the indicator meets the protocol target.

Table 17. Characteristics of Solar glare control – Daylight management indicator

Light Category	
Indicator Name	**56.p2.** Solar glare control – Daylight management
Objective	To avoid glare from the sun by blocking or reflecting direct sunlight away from occupants.[75]
Background	Though bright light during the day is conducive to good health, uneven levels of brightness in the visual field can cause visual fatigue and discomfort. Glare, or excessive brightness, is caused by light scattering within the eye (intraocular scattering), thereby creating a "veil" of luminance that reduces the luminance contrast as received by the retina. In buildings, sources of glare are often unshielded or poorly shielded light, or sunlight directly hitting the eye or reflective surfaces. [75] 
Protocol Target	At least one of the following is required for all glazing greater than 2.1m above the floor in regularly occupied spaces (excluding lobbies): a. Interior window shading or blinds that are controllable by the occupants or set to automatically prevent glare. b. External shading systems that are set to automatically prevent glare. c. Interior light shelves to reflect sunlight toward the ceiling. d. A film of micro-mirrors on the window that reflects sunlight toward the ceiling. e. Variable opacity glazing, such as electrochromic glass, which can reduce transmissivity by 90% or more. [75]
Assessment methodology	The indicator assessed by measuring and an on-site survey.
Calculating Process	First using the DWG documents (plan,section and view) and measuring the distance between windows and floors, Then onsite checking of the windows to confirm the above-mentioned requests.
Result	According to the section, the distance between windows and floor is more than 2.1m and by visual inspection, it has captured that all the windows have external shadings. Shading is controllable manually by students and windows have the interior blinds which are controllable by students. The blinds are new and they have been added because many teachers who use projecting contents have to have a lower luminance in the room. In addition to measuring the distance between windows from chairs and desks, as well as the floor, a few examples of interior classroom photographs, can indicate an approximate distance between them and provide a better understanding of the interior design of the classroom 1. So, this indicator meets the protocol target.

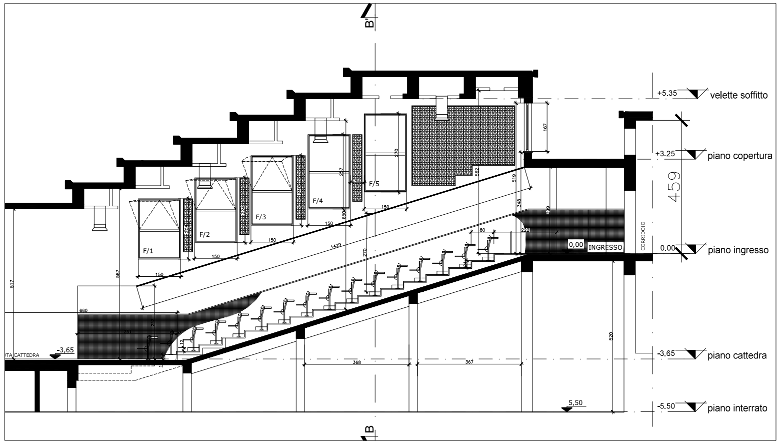


Figure 15. Section of classroom 1, Politecnico di Torino
Source: Area Edilog, Polythechnic University of Turin, October 2019

Figure 29. Interior pictures of classroom1, Politecnico di Torino
Source: Photographs by Farzaneh Aliakbari, October 2019

In this part, it is attempted to provide a summary of the indicator validation process. From the final list, after the questionnaire, only seven indicators were taken to the next stage because the information was available for them. Indicators were evaluated in a variety of ways and were performed accurately. In this route, the plan, section and some photographs were used and all measurements were carried out from section and plan in addition to the in situ measuring. On the other hand, some indicators needed the approval of the relevant experts, and a series of issued laws were studied to confirm them. Three indicators were in the air category and after evaluating them on the case study, it has found out that only two indices are observing the protocol threshold. Besides, the light category had four indicators, and only three indicators met the Protocol target. Thus, the number of indicators that observed the threshold of the protocol reached five following the conditions set out in the protocol (see Table 18). As can be seen in the table below a list of indicators with the data verification result has provided. Five indicators over the seven indicators such as; **02.p1.** Smoking ban, **05.p2.** Air filtration, **56.p2.** Solar glare control and Daylighting fenestration (part 1 & part 2), meet the protocol target, while only two indicators, named at **16.p1.** Humidity control and **61.p2.** Right to light, do not meet the threshold of the protocol.

Table 18. List of data verified indicators

Category	Indicators	Threshold	Data Verified
Air	**16.p1.** Humidity Control- Relative Humidity	30% < RH < 50% All Operation hours	
	02.p1. Smoking ban - Indoor smoking ban	Smoking is forbidden	●
	05.p2. Air filtration- Particle filtration	Filters MERV 13 or Higher	●
Light	**63.p1.** Daylighting fenestration- Window sizes for working and learning spaces	If 40% < widow-wall ratio < 60% Requires External shadings	●
	61.p2. Right to light- Window access for working and learning spaces	75% of all desks are within 7.5 m of a window with views to the exterior	
	63.p2. Daylighting fenestration- Window Transmittance in Working & Learning Areas	All glazing VT > 60%	●
	56.p2. Solar glare control – Daylight management	Windows 2.1m above floor require blindes	●

4.2.2 Recommendations

This research aims at Proposing some recommendations to improve the indoor quality of the classroom, make a better environment for students and promote students' health. Experts' suggestions on improving the classroom environment are worth mentioning. After the data verification process which has been done in the previous part, it has captured that the Relative humidity level in the classroom 1 at Polito campus is not in equilibrium and should be upgraded by changing the air ventilation system plant. Also, using Photocatalytic oxidation technology into the central ventilation system can remediate air pollution and helps to purify the indoor air. Considering the issues related to the light category, it has suggested to install automated shading devices and light sensors to control the unwanted heat and light. These suggestions should be broadly explored in the future as well as try to run them in the classroom 1 at Polito campus to improve indoor conditions and students feel healthier while educating. Table 19 shows the list of recommendations that should take in consideration for applying on the classroom 1. As can be seen in the table, these suggestions could develop those indicators which have not been fulfilled during the data verification. Two indicators are related to the Air category which are Humidity Control, Advanced Air Purification, and one indicator; Automated shading and dimming controls belongs to the Light category. Improving these indicators reduces the health issues observed in the classroom like Skin, eyes, respiratory irritation, throat, Psychological and neurological Problems.

Table 19. Recommendations proposed by the relevant experts

Category	Indicators	Recommendations
Air	**16.p1.** Humidity Control- Relative Humidity	Improving ventilation system to maintain RH
	23.p2. Advanced Air Purification - Air Sanitization	Using Photocatalytic oxidation Technology into the central ventilation system or as a standalone device.
Light	**60.p2.** Automated shading and dimming controls- Automated sunlight control	Installing automatic shading devices and light sensors

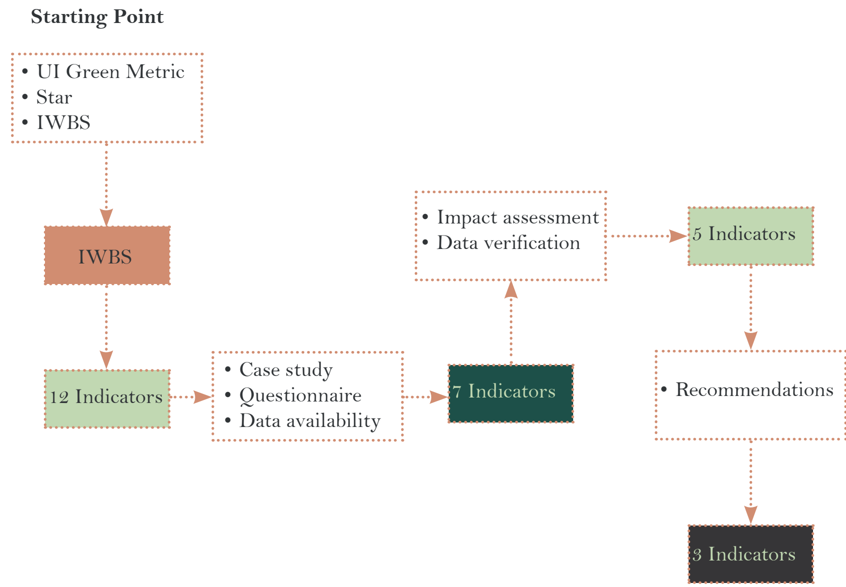


Figure 30. Schematic summarization of results

5 Conclusion

During the research activity, different steps were done carefully. In the first step, three different assessment tools such as Star, UI Green Metric and International well-building standard (IWBS) which were applicable on the educational buildings were analyzed and the IWBS protocol was selected as the only protocol that emphasized 100% on the student's health. Then, those indicators that emphasize on the health of students and have a greater impact on their performance and health were chosen. To accomplish that, all the three protocols were examined to find the similar and common indicators among the three studied protocols. It is noteworthy that all the indicators of the selected protocol (IWBS) were aimed at comparing the protocols for selecting the indicator only to find similarities and commonalities between them. Eventually, several indicators divided into seven categories were selected and linked to the health aspects to understand better about the health issues and their relationship to the environment in which people live. At this point, the number of indicators decreased from 105 to 40. During the next step, it has tried to reduce the number of indicators and select the most important ones relating to the health. Since the case study was an interior part of the university building and no external environmental factors were involved, it has decided to ignore those indicators related to the water, nutrition, outdoor air, fitness, mind categories.

With this method, the number of indicators reached to 20 divided into indoor air and light categories. 8 indicators were related to the indoor air category and 12 indicators belonged to the Light category. As the number of indicators was still high, it has tried to filter the indicators. Since, it was difficult to choose between the indicators, decided to ask the relevant experts' opinion. To this end, an online questionnaire for all the 20 indicators was prepared and sent to the 80 relevant experts at the Energy Department of the Politecnico di Torino. It was asked to rate the indicators according to the understandability, measurability, and relevancy of indicators to the student's health. Scores were ranged from 0 to 4 and if they had no information about the indicator they could state that I do not know (DK). At the end of the Questionnaire process, only 12 indicators were scored higher than the overall average and they were identified as the most important indicators that have a great impact on the health of students. According to the data availability only seven indicators were selected and the rest of indicators had no information, and due to the existing conditions it was difficult to gather information about, so it was only possible to evaluate the 7 indicators. Among these 7 indicators, 3 of them were related to the air section and 4 to the light section. Some of the indicators were evaluated visually on the site and the others were examined by specialized software and using Architectural drawings. After the data verification, it was concluded that some of the indices that have been applied in the classroom were already weak and did not meet the protocol thresholds. The number of these indicators was 2, while 5 indicators, fulfilled the requirements stated in the protocol. Lack of any of these indicators in the classroom induces a health problem in the students' physical system. For example, if the relative humidity level in the classroom is not in a specified range listed in the protocol causes respiratory problems for students. Besides, if students receiving too much light when they are in the class, it causes negative effects in their brain, decreases their brain efficiency and they become distracted. Therefore, it is important to make sure that the indicators are used correctly, not to disturb the nervous system and their general health. Through this thesis, the two questions asked in the first part of the research got answers and it was showed how it is important to identify the most relevant indicators regards

the health of students and make the assessment to improve the indoor quality as well as student's health.

The following part is an attempt to highlight the important points obtained from the research. At the current situation of classroom 1 at Politecnico di Torino some power points and weak points were recognized as outlined below.

The power points are;

- Lack of smoke pollution
- Filters placed inside the air handling unit correspond to MERV 15
- Presence of external shadings for the windows and controlling unwanted heat gain and glare

The weak points are;

- The relative humidity level is not good
- The HVAC system has no device to control HR
- Windows are above the students' heads and lack of views to the exterior

These weak points causes health issues;

- Respiratory irritation
- Throat
- Weakness in psychological and neurological gains

The recommendations given by relevant experts are;

- Upgrading the ventilation system
- Using Photocatalytic oxidation Technology into the central ventilation system
- Installing automatic shading devices and light sensors

The further steps for the future development of the Polito campus are;

- Student's involvement in the research
- Considering more indicators
- Providing specialized tools for measuring indicators
- Considering sufficient budget to apply and measure indicators
- Collecting more data

Future student engagement is crucial to the development of this research. Because their views of the classroom can have an effective role in determining and recognizing the quality of the indoor environment. By involving students in the research and developing a questionnaire on general health, problems with indoor quality can be identified and their satisfaction about the classroom can be understood. Sometimes students feel headaches, dizziness or even shortness of breath when they are in the classroom and these health problems maybe are related to low indoor air quality. So, employing students would be helpful during the research process to understand better the relationship between campus settings and students' health. According to the research that has been done so far and due to the various limitations that will be mentioned in the next section, the number of indicators that were on the evaluation path were limited, so in the future by solving the constraints can discover more indicators which are related to students health. Also, in the process of evaluating the indicators and collecting data, more attention should be paid to collaborating with relevant experts and providing specialized tools for measuring the indicators, as well as considering sufficient budget to apply the indicators in the classroom and measuring them. These future consideration reduces the health problems for students and improves their academic achievements during the time. Figure 31 shows the schematic design of the conclusion part of this research.

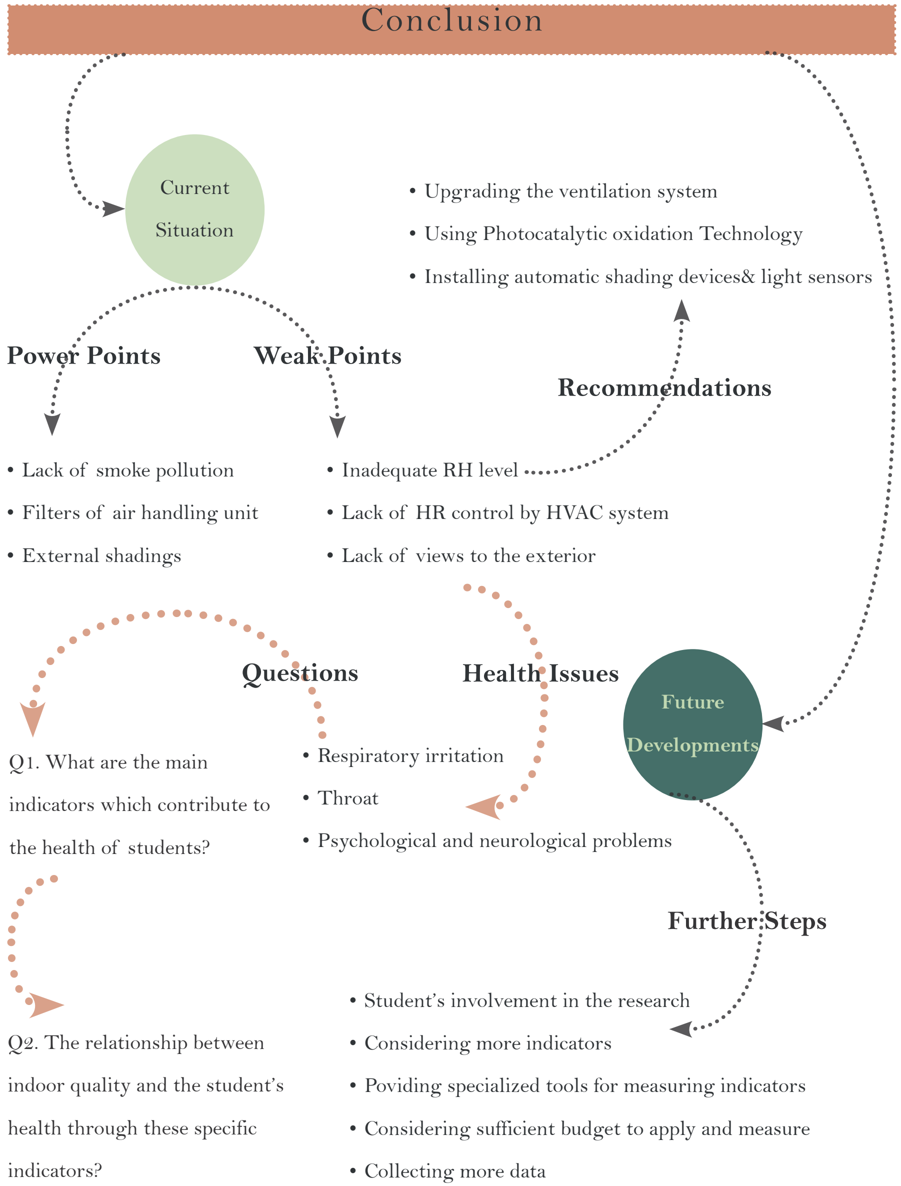


Figure 31. Schematic overview of Conclusion

5.1 Limitations

During the research process, various limitations and difficulties slowed the progress of the research. One of the limitations was related to the timing of the thesis because the experts in the questionnaire process were late in answering the questions and wasted a lot of time at this stage. On the other hand, according to the planning done before the questionnaire, the aim was to ask the questions to each expert through a personal interview but unfortunately, they did not have enough time to conduct the interview and decided to complete the questionnaire through online forms. This has led to the lack of discussion on the indicators development and has led to did not get all their suggestions on how to develop the indicators for improving indoor quality of classroom 1 and expanding it to the whole campuses of Politecnico di Torino. The next problem was the difficulty of data collection for the impact assessment of indicators. It was impossible to verify some indicators and measure them because some of them needed sensors to be measured and there was insufficient budget and also lack of technical experts to help at measuring and verifying them. It was one of the reasons that we were limited to the datasets available at the data lab of Polito campus and thus removed several indicators from the evaluation list. However, there is a hope that shortly these limitations could be resolved and all indicators related to well building standard protocol can be implemented and evaluated and try to enhance indoor comfort and minimize student health problems.

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Appendices

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A

Email template

Dear …

My name is Farzaneh Aliakbari. I am an undergraduate master student of Architecture for the sustainability design at Politecnico di Torino. My thesis topic is "Development and assessment of wellbeing Indicators of an educational building". This thesis aims at selecting a set of wellbeing indicators from well building a standard assessment tool to be used for assessing the indoor quality of a classroom.

I am looking for participants for the questionnaire part of my research. I would like to ask you questions relating to your perspectives on indicator development.

Please reply to this email to express your interest, and to send you the questionnaire.

Thank you very much for your consideration.

Sincerely yours

Farzaneh Aliakbari

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B

Questionnaire

Questionnaire guide

Relevant Experts in the field including Green team members, Professors and the master plan of the Polito campus.

Objective

The purpose of this Questionnaire is to identify the most important indicators from Well Building Standard Protocol contributing to the student's health.

Confidentiality

Any data and information given in this questionnaire will be treated strictly confidential and will not be transferred to any third parties. Participants interested in getting actively engaged in our research projects are encouraged to fill in their contact details at the end of this questionnaire. We will then be in touch shortly.

Questions related to indicators

From your perspective, please answer the following questions that you consider most important to implement for achieving student's health and well-being in the university classrooms from the list below.

1. Is the indicator understandable?
2. Is the indicator measurable?
3. Is the indicator relevant to the student's health?

AIR CATEGORY

https://docs.google.com/forms/d/1nEcMG9ioLly2fXLD7LPXkwt088cjvTx2ZFxOS1O5_s/edit#responses

Understandable:
0- Not understandable ; 1- Less understandable; 2- Moderately understandable; 3- Understandable; 4- Very understandable; DK- Does not know
Relevant:
0- Not Relevant; 1- Less Relevant; 2- Moderately Relevant; 3- Relevant; 4- Very Relevant; DK – Does not know
Measurable:
0- Not measurable; 1- Difficult measurable; 2- Moderately measurable; 3-Measurable; 4- Easy measurable; DK – Does not know

1. Humidity Control- Relative Humidity

To limit the growth of pathogens, reduce off-gassing, and maintain thermal comfort by providing the appropriate level of humidity.

	0	1	2	3	4	DK
Relevant	○	○	○	○	○	○
Understandable	○	○	○	○	○	○
Measurable	○	○	○	○	○	○

2. Fundamental material safety - Asbestos and lead restriction

To reduce or eliminate occupant exposure to lead, asbestos, and polychlorinated biphenyls (PCBs) from building materials.

	0	1	2	3	4	DK
Relevant	○	○	○	○	○	○
Understandable	○	○	○	○	○	○
Measurable	○	○	○	○	○	○

3. Advanced Air Purification - Air Sanitization

To improve recirculated indoor air quality through the implementation of advanced air purification.

	0	1	2	3	4	DK
Relevant	○	○	○	○	○	○
Understandable	○	○	○	○	○	○
Measurable	○	○	○	○	○	○

4. Air flush – Air flush

To remediate construction-related indoor air contamination.

	0	1	2	3	4	DK
Relevant	○	○	○	○	○	○
Understandable	○	○	○	○	○	○
Measurable	○	○	○	○	○	○

5. Smoking ban - Indoor smoking ban

To deter smoking, minimize occupant exposure to second hand smoke, and reduce smoke pollution.

	0	1	2	3	4	DK
Relevant	○	○	○	○	○	○
Understandable	○	○	○	○	○	○
Measurable	○	○	○	○	○	○

6. Air filtration – Particle filtration

To remove indoor and outdoor airborne contaminants through air filtration.

	0	1	2	3	4	DK
Relevant	○	○	○	○	○	○
Understandable	○	○	○	○	○	○
Measurable	○	○	○	○	○	○

7. Construction pollution management – Filter replacement

To minimize the introduction of construction-related pollutants into indoor air and protect building products from degradation, all filters are replaced prior to occupancy.

	0	1	2	3	4	DK
Relevant	○	○	○	○	○	○
Understandable	○	○	○	○	○	○
Measurable	○	○	○	○	○	○

8. Operable windows - Full control

To increase the supply of high quality outdoor air and promote a connection to the outdoor environment by encouraging occupants to open windows when outdoor air quality is acceptable.

	0	1	2	3	4	DK
Relevant	○	○	○	○	○	○
Understandable	○	○	○	○	○	○
Measurable	○	○	○	○	○	○

LIGHT CATEGORY

https://docs.google.com/forms/d/1ENPkxF5kNX12Jg-9XYtEb7NhI-L68bpVxjBI-Foo1fU/edit#responses

Understandable:

0- Not understandable ; 1- Less understandable; 2- Moderately understandable; 3- Understandable; 4- Very understandable; DK- Does not know

Relevant:

0- Not Relevant; 1- Less Relevant; 2- Moderately Relevant; 3- Relevant; 4- Very Relevant; DK – Does not know

Measurable:

0- Not measurable; 1- Difficult measurable; 2- Moderately measurable; 3-Measurable; 4- Easy measurable; DK – Does not know

1. Automated shading and dimming controls- Automated sunlight control

To prevent glare and encourage reliance on natural light through automated shading and dimming.

	0	1	2	3	4	DK
Relevant	○	○	○	○	○	○
Understandable	○	○	○	○	○	○
Measurable	○	○	○	○	○	○

2. Daylighting fenestration – Window sizes for working and learning spaces

To optimize occupant exposure to daylight and limit glare through enhanced fenestration parameters.

	0	1	2	3	4	DK
Relevant	○	○	○	○	○	○
Understandable	○	○	○	○	○	○
Measurable	○	○	○	○	○	○

3. Right to light – Window access for working and learning spaces

To promote exposure to daylight and views of varying distances by limiting the distance workstations can be from a window or atrium.

	0	1	2	3	4	DK
Relevant	○	○	○	○	○	○
Understandable	○	○	○	○	○	○
Measurable	○	○	○	○	○	○

4. Electric lighting glare control – Glare minimization

To minimize direct and overhead glare by setting limits on the luminous intensity of luminaires.

	0	1	2	3	4	DK
Relevant	○	○	○	○	○	○
Understandable	○	○	○	○	○	○
Measurable	○	○	○	○	○	○

5. Visual lighting design –Visual Acuity for Learning

To support visual acuity by setting a threshold for adequate light levels and requiring luminance to be balanced within and across indoor spaces.

	0	1	2	3	4	DK
Relevant	○	○	○	○	○	○
Understandable	○	○	○	○	○	○
Measurable	○	○	○	○	○	○

6. Low-glare workstation design- glare avoidance

To minimize visual discomfort by situating computer monitors in a way that avoids glare and luminance contrast.

	0	1	2	3	4	DK
Relevant	○	○	○	○	○	○
Understandable	○	○	○	○	○	○
Measurable	○	○	○	○	○	○

7. Color quality – Color rendering index

To enhance spatial aesthetics and color differentiation through the use of lamps with quality color rendering abilities.

	0	1	2	3	4	DK
Relevant	○	○	○	○	○	○
Understandable	○	○	○	○	○	○
Measurable	○	○	○	○	○	○

8. Daylight modelling – Healthy sunlight exposure

To support circadian and psychological health by setting thresholds for indoor sunlight exposure.

	0	1	2	3	4	DK
Relevant	○	○	○	○	○	○
Understandable	○	○	○	○	○	○
Measurable	○	○	○	○	○	○

9. Surface design – Working and learning area surface reflectivity

To increase overall room brightness through reflected light from room surfaces and avoiding glare.

	0	1	2	3	4	DK
Relevant	○	○	○	○	○	○
Understandable	○	○	○	○	○	○
Measurable	○	○	○	○	○	○

10. Daylighting fenestration – Window Transmittance in Learning Areas

To optimize occupant exposure to daylight and limit glare through enhanced fenestration parameters.

	0	1	2	3	4	DK
Relevant	○	○	○	○	○	○
Understandable	○	○	○	○	○	○
Measurable	○	○	○	○	○	○

11. Circadian Lighting Design- Melanopic Light Intensity in Learning Areas

To support circadian health by setting a minimum threshold for daytime light intensity.

	0	1	2	3	4	DK
Relevant	○	○	○	○	○	○
Understandable	○	○	○	○	○	○
Measurable	○	○	○	○	○	○

12. Solar glare control – Daylight management

To avoid glare from the sun by blocking or reflecting direct sunlight away from occupants.

	0	1	2	3	4	DK
Relevant	○	○	○	○	○	○
Understandable	○	○	○	○	○	○
Measurable	○	○	○	○	○	○

Questionnaire RESPONSES

Air category

Email Address	1. Humidity Control- Relative Humidity [Relevant]	1. Humidity Control- Relative Humidity [Understandable]	1. Humidity Control- Relative Humidity [Measurable]	2. Fundamental material safety - Asbestos and lead restriction [Relevant]	2. Fundamental material safety - Asbestos and lead restriction [Understandable]	2. Fundamental material safety - Asbestos and lead restriction [Measurable]	3. Advanced Air Purification - Air Sanitization [Relevant]	3. Advanced Air Purification - Air Sanitization [Understandable]	3. Advanced Air Purification - Air Sanitization [Measurable]	4. Air flush – Air flush [Relevant]	4. Air flush – Air flush [Understandable]	4. Air flush – Air flush [Measurable]	5. Smoking ban - Indoor smoking ban [Relevant]	5. Smoking ban - Indoor smoking ban [Understandable]	5. Smoking ban - Indoor smoking ban [Measurable]	6. Air filtration – Particle filtration [Relevant]	6. Air filtration – Particle filtration [Understandable]	6. Air filtration – Particle filtration [Measurable]	7. Construction pollution management – Filter replacement [Relevant]	7. Construction pollution management – Filter replacement [Understandable]	7. Construction pollution management – Filter replacement [Measurable]	8. Operable windows - Full control [Relevant]	8. Operable windows - Full control [Understandable]	8. Operable windows - Full control [Measurable]
alessandro.gueccia@polito.it	4	3	3	3	3	3	4	3	3	2	2	2	4	3	2	4	3	2						
antonio.froio@polito.it	4	3	4	4	4	DK	3	3	3	2	3	1	4	4	4	3	3	3	3	1	2	3	4	0
stefano.dambrosio@polito.it	3	4	4	4	4	3	4	4	3	4	3	3	4	4	4	3	4	3	2	3	2	3	4	3
giorgia.spigliantini@polito.it	3	2	4	2	2	1	3	3	2	2	2	1	4	4	3	3	3	3	4	4	4	3	3	1
Paolo.tronville@polito.it	4	4	4	3	4	4	3	4	4	DK	DK	DK	4	4	4	4	4	4	4	4	4	4	4	4
fabrizio.tondaroc@polito.it	4	4	4	4	4	4	4	4	3	4	4	4	4	4	4	4	4	4	4	3	3	0	DK	DK
gianni@carioni.eu	4	4	4	4	4	4	4	4	DK	DK	DK	DK	4	4	4	4	4	4	4	4	4	4	4	4
luca.pulvirenti@polito.it	4	3	2	4	0	0	4	3	3	4	3	2	4	3	2	4	3	2	4	3	2	4	4	4
andrea.lanzini@polito.it	2	4	4	4	4	3	4	4	3	DK	4	4	4	4	0	4	4	2	3	2	1	4	4	3
cheekubadshah82@gmail.com	2	2	2	3	2	1	4	3	4	4	3	3	4	4	4	3	3	2	4	3	2	4	3	3
domenico.ferrero@polito.it	4	3	2	4	1	0	2	3	DK	DK	DK	DK	3	3	1	4	4	1	3	4	4	4	DK	0
marco.cavana@polito.it	4	2	3	4	4	3	3	3	3	3	2	2	4	4	3	1	1	2	3	2	1	4	4	2
raffaella.gerboni@polito.it	4	4	4	4	4	3	4	4	3	3	2	4	4	4	4	4	4	3	3	2	2	2	1	1
arianna.astolfi@polito.it	1	2	4	4	4	DK	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	4	DK
paolo.deangelis@polito.it	3	3	4	DK	3	4	3	3	4	4			2	3	1	3	3	3	3	3	2	4	3	2
laura.rietto@polito.it	4	3	4	4	4	DK	3	3	3	2	1	DK	4	4	DK	4	4	4	4	4	DK	3	2	DK
FURLAN ROBERTO <d019525@polito.it>	4	2	3	4	3	3	4	4	3	4	2	3	4	4	4	4	3	3	4	2	3	4	4	3
roberto.bonifetto@polito.it	4	3	3	DK	DK	DK	4	4	1	3	2	DK	4	4	1	3	3	2	2	2	1	3	3	2
emanuele.giamello@polito.it	3	4	4	4	2	DK	3	4	2	3	1	DK	4	4	4	3	3	3	4	4	3	4	4	1
vincenzo.cirimele@polito.it	4	3	3	4	2	DK	4	4	DK	4	4	DK	4	4	3	3	2	3	3	3	DK	2	2	DK
giovanni.fracastoro@polito.it	3	4	3	2	1	1	1	2	3	3	3	1	4	4	1	3	3	3	3	3	3	4	4	2
giulio.cerino@polito.it	3	3	4	4	4	3	3	3	3	DK	2	DK	4	4	2	3	3	3	3	2	2	3	3	2
franco.quarona@polito.it	3	3	3	4	4	3	2	3	3	3	2	2	1	3	3	2	2	3	3	3	3	4	4	4
simone.salvadori@gmail.com	4	3	3	DK	DK	DK	4	4	3	4	4	DK	4	4	DK	4	4	DK	4	4	DK	4	4	DK
alessandro.alberico@polito.it	4	3	3	2	3	DK	4	3	3	3	3	DK	4	4	4	3	1	3	2	4	3	2	3	DK
andrea.carpignano@polito.it	3	4	4	4	4	4	4	4	4	3	4	3	4	4	4	3	4	3	4	4	4	4	4	3
massimo.santarelli@polito.it	4	2	3	4	3	3	3	3	3	4	3	3	3	3	3	3	3	3	3	3	3	4	3	3
andrea.prato@polito.it	3	2	4	2	1	2	3	3	3	1	2	2	3	2	3	3	3	4	2	1	1	4	4	4
roberto.finesso@polito.it	4	3	4	4	4	4	3	4	2	DK	DK	DK	4	4	DK	4	4	DK	4	4	DK	2	4	2
paduos@c2rconsulting.com	4	3	3	2	2	3	4	2	3	1	1	1	3	4	2	1	1	2	2	1	2	1	0	1
luciano.rolando@polito.it	3	4	4	4	4	4	4	2	4	2	2	2	4	4	4	3	3	3	4	4	4	4	3	1
gianfranco.chicco@polito.it	4	3	3	4	2	DK	4	4	DK	4	2	DK	3	2	DK	4	3	DK	4	3	3	4	4	DK
alberto.tenconi@polito.it	3	3	3	DK	DK	DK	3	3	3	3	3	3	3	4	DK	3	4	DK	DK	DK	DK	4	4	DK
umberto.lucia@polito.it	4	2	1	4	4	1	4	4	4	4	4	1	4	4	4	4	4	3	4	4	4	4	4	4
filippo.spertino@polito.it	4	4	4	4	4	4	4	4	4	3	3	2	4	4	4	4	4	4	4	4	4	4	4	3
nicolo.abrate@polito.it	3	4	2	4	4	4	4	4	4	2	2	2	4	4	4	4	4	4	4	4	4	4	4	4
daniele.lerede@polito.it	3	3	3	4	2	3	3	4	2	4	4	4	4	4	4	4	3	3	2	2	3	4	4	4
francesco.profumo@polito.it	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
federico.piglione@polito.it	1	2	3	4	1	3	4	3	DK	4		DK	4	4	3	3	3	3	4	4	4	3	3	3
d016858@polito.it	4	4	DK	4	4	4	4	4	DK	DK	DK	DK	DK	4	DK	1	1	1	1	1	1	4	4	1

Source: https://docs.google.com/spreadsheets/d/1D6DLPWcujw4dMXZoX3l2wCbAgHpOVttmWyjGquygT2I/edit?usp=sharing

Light category

Email Address	1. Automated shading and dimming controls- Automated sunlight control [Relevant]	1. Automated shading and dimming controls- Automated sunlight control [Understandable]	1. Automated shading and dimming controls- Automated sunlight control [Measurable]	2. Daylighting fenestration – Window sizes for working and learning spaces [Relevant]	2. Daylighting fenestration – Window sizes for working and learning spaces [Understandable]	2. Daylighting fenestration – Window sizes for working and learning spaces [Measurable]	3. Right to light – Window access for working and learning spaces [Relevant]	3. Right to light – Window access for working and learning spaces [Understandable]	3. Right to light – Window access for working and learning spaces [Measurable]	4. Electric lighting glare control – Glare minimization [Relevant]	4. Electric lighting glare control – Glare minimization [Understandable]	4. Electric lighting glare control – Glare minimization [Measurable]	5. Visual lighting design –Visual Acuity for Learning [Relevant]	5. Visual lighting design –Visual Acuity for Learning [Understandable]	5. Visual lighting design –Visual Acuity for Learning [Measurable]	6. Low-glare workstation design- glare avoidance [Relevant]	6. Low-glare workstation design- glare avoidance [Understandable]	6. Low-glare workstation design- glare avoidance [Measurable]	7. Color quality – Color rendering index [Relevant]	7. Color quality – Color rendering index [Understandable]	7. Color quality – Color rendering index [Measurable]	8. Daylight modelling – Healthy sunlight exposure [Relevant]	8. Daylight modelling – Healthy sunlight exposure [Understandable]	8. Daylight modelling – Healthy sunlight exposure [Measurable]	9. Surface design – Working and learning area surface reflectivity [Relevant]	9. Surface design – Working and learning area surface reflectivity [Understandable]	9. Surface design – Working and learning area surface reflectivity [Measurable]	10. Daylighting fenestration – Window Transmittance in Working and Learning Areas [Relevant]	10. Daylighting fenestration – Window Transmittance in Working and Learning Areas [Understandable]	10. Daylighting fenestration – Window Transmittance in Working and Learning Areas [Measurable]	11. Circadian Lighting Design- Melanopic Light Intensity in Learning Areas [Relevant]	11. Circadian Lighting Design- Melanopic Light Intensity in Learning Areas [Understandable]	11. Circadian Lighting Design- Melanopic Light Intensity in Learning Areas [Measurable]	12. Solar glare control – Daylight management [Relevant]	12. Solar glare control – Daylight management [Understandable]	**12. Solar glare control – Daylight management [Measurable]**
	4	4	DK	3	2	2	2	1	DK	3	2	DK	3	2	DK	2	3	DK	3	4	3	4	3	3	3	2	3	3	4	4	1	1	1	4	3	3
	3	2	3	4	4	4	3	3	2	3	3	3	3	0	DK	4	4	1	1	2	0	3	0	DK	2	3	1	3	3	1	1	0	DK	1	3	2
	4	3	3	3	3	3	2	3	3	3	3	3	2	2	DK	3	2	DK	2	3		1	1	DK	2	4	2	2	3	3	DK	0	DK	2	3	3
	3	3	4	4	4	3	4	4	3	3	3	4	3	3	4	4	4	4	DK	DK	3	DK	DK	4	3	3	4	3	3	4	DK	DK	4	3	3	4
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	3	3	3	3	2	DK	3	3	DK	3	2	2	4	3	3	4	4	4	3	2	DK	4	4	2	4	4	3	3	2	DK	DK	DK	DK	3	3	DK
	3	3	3	4	4	4	4	4	3	3	3	3	3	4	3	3	3	2	3	3	2	3	3	2	2	3	2	2	3	3	3	4	3	3	3	3
	3	2	2	3	1	1	DK	0	DK	2	3	3	DK	DK	DK	3	4	2	2	3	3	3	3	2	3	3	2	3	3	2	2	2	2	4	3	3
	2	2	4	4	4	4	4	3	3	4	4		4	3	4	3	2	3	3	3	3	4	4	4	1	1	1	4	3	3	3	3		2	1	2
stefano.dambrosio@polito.it	3	3	4	3	3	2	4	4	3	2	3	3	3	3	3	4	4	3	3	4	3	DK	DK	DK	1	3	2	3	3	3	DK	DK	DK	2	4	3
giorgia.spigliantini@polito.it	2	2	4	4	4	4	3	3	3	3	2	2	3	3	3	3	3	3	2	2	2	2	2	1	2	2	2	3	3	3	2	2	2	3	2	2
fabrizio.tondaroc@polito.it	4	4	4	4	3	3	4	4	4	4	3	0	3	3	4	3	3	3	4	4	4	1	3	1	DK	DK	DK	3	2	0	DK	DK	DK	3	3	1
luca.pulvirenti@polito.it	4	4	3	4	4	4	4	4	4	4	3	3	4	4	4	4	4	4	3	3	3	4	4	4	3	3	3	2	2	2	3	3	3	2	2	2
antonio.froio@polito.it	4	1	3	3	3	0	2	3	3	4	3	3	4	3	4	4	4	3	0	2	1	2	0	0	1	0	0	3	0	1	4	DK	0	4	4	2
domenico.ferrero@polito.it	4	4	3	4	3	DK	DK	DK	DK	4	4	4	3	3	1	4	4	2	2	3	DK	3	1	DK	4	4	DK	4	3	DK	DK	3	DK	4	3	DK
marco.cavana@polito.it	2	2	1	4	4	2	4	3	2	4	3	3	4	2	2	3	2	1	3	4	2	4	4	3	3	3		3	3	2	4	4	3	4	4	3
raffaella.gerboni@polito.it	4	4	4	4	4	4	3	2	2	4	4	4	4	3	2	2	4	3	2	2	1	4	4	2	3	3	2	4	3	3	3	3	2	4	4	3
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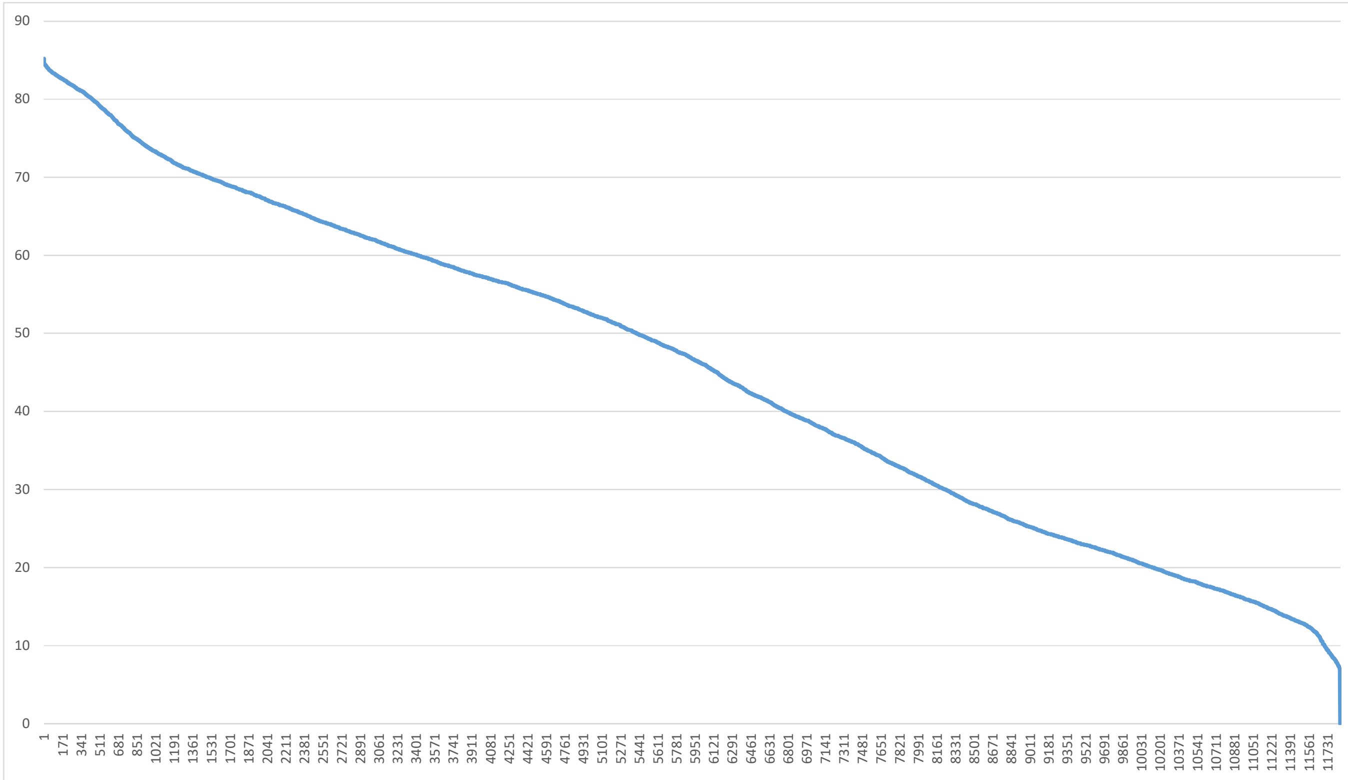
FURLAN ROBERTO <d019525@polito.it>	4	3	3	4	4	3	4	3	3	4	4	3	4	4	4	4	3	3	4	2	3	3	2	2	4	3	3	4	3	3	3	2	2	4	4	3
roberto.bonifetto@polito.it	3	2	1	4	3	2	4	3	3	4	3	1	4	2	1	4	3	2	4	2	1	3	1	1	3	1	1	3	2	2	2	2	1	3	2	2
emanuele.giamello@polito.it	4	3	4	4	4	3	4	4	4	3	2	4	4	4	4	3	3	2	4	2	4	4	3	3	3	3	3	4	4	3	4	2	3	2	3	3
ilaria.abba@polito.it	3	3	3	4	4	4	3	4	4	4	4	4	3	3	3	4	4	3	2	2	2	3	3	3	2	2	2	2	2	2	3	3	3	3	3	3
vincenzo.cirimele@polito.it	3	3	DK	4	4	DK	4	4	DK	4	4	3	3	3	3	3	3	DK	4	2	3	4	3	DK	3	2	DK	4	4	DK	4	3	DK	4	3	DK
giovanni.fracastoro@polito.it	2	2	2	4	4	4	3	2	2	2	2	2	3	3	3	3	3	2	4	4	2	2	3	3	2	2	1	3	3	3	3	3	2	3	3	2
giulio.cerino@polito.it	4	4	4	3	3	3	3	3	3	4	3	4	4	3	4	4	3	3	3	3	3	DK	DK	DK	2	3	2	3	3	3	DK	DK	DK	3	3	2
franco.quarona@polito.it	4	4	4	4	4	4	4	4	4				3	3	3	4	4	4	3	4	4	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4
simone.salvadori@gmail.com	4	4	DK	DK	DK	DK	3	3	DK	DK	DK	DK	DK	DK	DK	4	4	DK	DK	DK	DK	4	4	DK	DK	DK	DK	DK	DK	DK	4	4	DK	4	4	DK
alessandro.alberico@polito.it	3	3	3	2	3	3	2	3	3	1	1	DK	2	4	DK	4	2	DK	2	2	2	2	3	2	2	3	3	2	3	3	3	3	3	2	2	2
andrea.carpignano@polito.it	4	4	4	4	4	4	3	4	4	3	4	4	4	4	4	4	4	3	3	4	4	3	4	DK	3	4	DK	4	4	4	DK	DK	DK	4	4	4
andrea.prato@polito.it	4	4	3	3	3	3	2	3	3	0	3	1	3	3	4	4	3	4	1	2	1	4	4	4	2	1	1	3	3	2	4	4	4	3	3	2
roberto.finesso@polito.it	4	4	4	3	4	4	3	3	3	2	4	2	3	3	3	2	4	3	2	2	4	3	3	4	2	3	3	3	3	4	3	3	3	3	3	4
luciano.rolando@polito.it	4	2	3	3	2	3	4	3	2	3	2	3	4	2	4	4	4	4	DK	DK	DK	4	4	2	4	2	4	4	3	4	2	2	2	4	3	2
gianfranco.chicco@polito.it	3	3	3	3	3	3	4	3	3	3	2	DK	3	1	DK	4	4	3	3	3	3	3	3	DK	3	2	DK	DK	DK	DK	3	1		4	3	DK
alberto.tenconi@polito.it	4	4	3	4	4	3	3	3	3	3	3	3	2	2	DK	3	3	DK	DK	DK	DK	DK	DK	DK	3	3	3	3	3	3	DK	DK	DK	3	3	3
umberto.lucia@polito.it	4	4	4	4	4	4	4	4	2	4	4	3	4	4	2	4	4	3	4	4	2	4	4	3	4	4	3	4	4	3	4	4	4	4	4	4
filippo.spertino@polito.it	4	3	3	3	3	4	3	4	3	4	4	4	4	4	3	4	3	2	2	3	2	4	4	3	4	4	4	4	4	3	3	3	3	3	3	3
daniele.lerede@polito.it	2	3	2				4	3	1	1	2	3	4	4	4	4	3	1	1	2	1	3	3	3	3	1	1	3	2	3	3	3	1	3	2	3
francesco.profumo@polito.it	4	3	3	4	4	4	4	3	4	4	3	3	4	4	4	4	4	4	4	3	3	4	4	4	4	4	3	4	4	4	4	3	3	4	4	4
federico.piglione@polito.it	4	4	4	4	4	4	4	4	4	4	4	4	3	3	3	4	4	2	3	3	DK	3	3	3	3	3	3	4	3	4	3	3	3	4	4	3
d016858@polito.it	4	4	2	3	3	2	3	3	2	3	3	3	3	3	2	3	2	2	4	2	2	4	4	2	4	3	3	3	2	2	2	0	1	4	3	2

Source: https://docs.google.com/spreadsheets/d/1D6DLPWcujw4dMXZoX3l2wCbAgHpOVttmWyjGquygT2I/edit?usp=sharing

D

HR CHECK RESULT

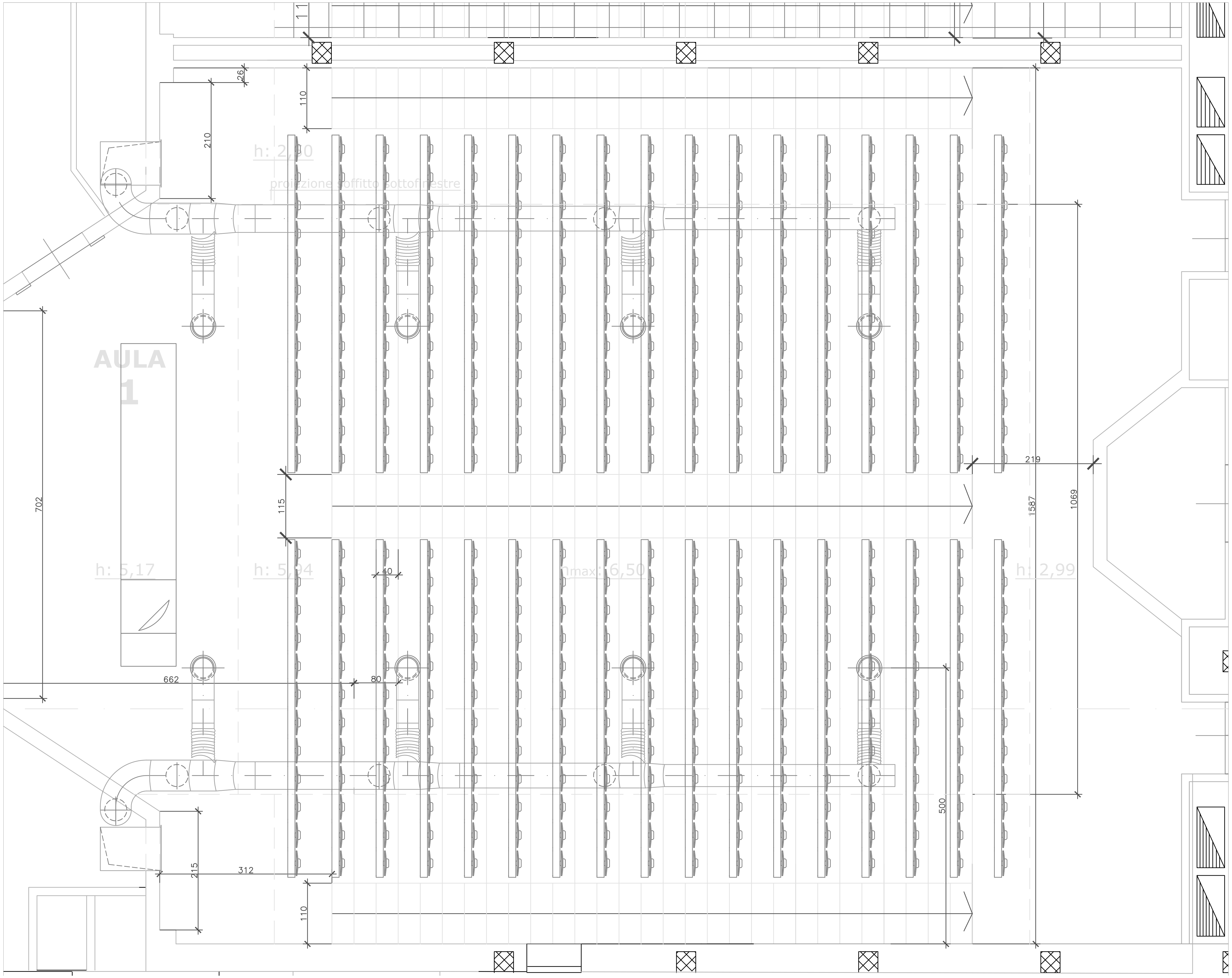
DATA_ORA_MINUTI_RILEVAMENTO_BASE	HRiaqMan	HRCheck	TiaqFF	TiaqMan	TiaqRip	Tman	TRipDX	TRipSX	TRipSX
6/6/2018 17:45	85.2	0	21.9	17.5	22.6	17.8	23.5	22.7	22.7
6/6/2018 18:00	85.2	0	22.1	19.3	22.7	19.3	23.5	23	23
6/4/2018 12:00	84.6	0	20.7	17.1	23.1	17.4	23.6	23.3	23.3
6/4/2018 12:15	84.6	0	20.7	17.1	23.3	17.4	24.1	23.3	23.3
6/4/2018 12:30	84.5	0	20.8	17	23.4	17.4	24.3	23.3	23.3
6/4/2018 13:00	84.5	0	20.9	16.9	23.4	17.4	24.2	23.3	23.3
6/4/2018 13:15	84.5	0	21.1	17.2	23.5	17.4	24.3	23.4	23.4
6/6/2018 17:30	84.5	0	22.2	16.8	23.1	17.5	23.6	23.2	23.2
5/30/2018 18:00	84.4	0	21.2	18.2	22.3	18.9	23	22.5	22.5
5/30/2018 18:15	84.4	0	21.1	18.9	22.3	19	23	22.5	22.5
6/4/2018 11:30	84.4	0	20.9	17	22.8	17.4	23.3	23.2	23.2
6/4/2018 12:45	84.4	0	20.9	16.9	23.4	17.4	24.1	23.2	23.2
6/6/2018 16:45	84.4	0	22.7	17.4	23.7	17.5	24.3	23.7	23.7
6/6/2018 17:00	84.4	0	22.7	17.3	23.7	17.5	24.2	23.6	23.6
6/11/2018 11:45	84.4	0	22.5	17.5	23	17.7	23.5	23.3	23.3
6/4/2018 11:45	84.3	0	20.8	17.1	22.9	17.4	23.4	23.2	23.2
6/4/2018 13:30	84.3	0	21.1	17.6	23.3	17.5	23.5	23.2	23.2
7/13/2018 8:15	84.3	0	22.3	17.9	22.7	18.2	23.1	22.8	22.8
7/13/2018 8:30	84.3	0	22.5	18.4	22.9	19	23.2	23	23
7/17/2018 8:00	84.3	0	21.1	17.8	22.4	18.1	22.8	22.3	22.3
5/29/2018 10:30	84.2	0	20.4	17.5	22.3	17.9	22.9	22.7	22.7
5/29/2018 19:30	84.2	0	23.7	18.3	23.8	19.1	23.1	23.3	23.3
5/30/2018 17:30	84.2	0	21.3	18.5	22.7	19	23.1	23.1	23.1
6/11/2018 12:00	84.2	0	22.7	18.2	23.2	18.6	23.7	23.4	23.4
7/16/2018 18:45	84.2	0	21.8	18.5	23.1	19	23.2	23.2	23.2
5/29/2018 10:15	84.1	0	20.4	16.8	22.5	17.3	23	22.8	22.8
6/4/2018 10:45	84.1	0	21.1	16.6	22.8	17.4	23.3	23.1	23.1
6/6/2018 17:15	84.1	0	22.6	16.9	23.6	17.5	24	23.5	23.5
7/17/2018 8:15	84.1	0	21.1	18.5	22.4	18.9	22.8	22.2	22.2
5/30/2018 17:15	84	0	20.6	18	22.9	18.8	23.2	23.1	23.1
6/4/2018 11:15	84	0	21	16.8	22.8	17.5	23.3	23.1	23.1
6/4/2018 13:45	84	0	21.3	17.9	23.4	18.2	24.4	23.4	23.4
6/11/2018 12:15	84	0	23.2	18.4	23.6	19.2	24.7	23.5	23.5
7/12/2018 8:15	84	0	23.2	18.8	23	19.2	23.3	23.1	23.1
7/13/2018 9:00	84	0	23.1	18.7	23.3	19.1	23.8	23.2	23.2
9/17/2018 8:00	84	0	21.6	19.3	22.6	19.4	22.8	22.7	22.7
5/30/2018 17:45	83.9	0	21.3	18.2	22.6	18.9	23	22.8	22.8
6/4/2018 11:00	83.9	0	21.1	16.8	22.8	17.5	23.3	23.2	23.2
6/4/2018 14:00	83.9	0	21.5	18.2	23.7	18.9	24.9	23.6	23.6
7/13/2018 8:45	83.9	0	22.8	18.6	23.2	19.1	23.5	23.2	23.2
7/13/2018 10:00	83.9	0	23.8	19	23	19.1	23.2	23.2	23.2
7/16/2018 19:15	83.9	0	21.8	18.6	23.1	19.1	23.2	23.1	23.1
9/22/2018 8:45	83.9	0	22	19.3	22.4	19.7	22.7	22.5	22.5
6/6/2018 16:30	83.8	0	23.2	17.7	23.8	17.7	24.8	23.7	23.7
6/7/2018 10:45	83.8	0	22.5	17.1	22.5	17.6	23.4	22.6	22.6
6/11/2018 12:30	83.8	0	23.5	18.8	23.8	19.3	25	23.7	23.7
7/11/2018 8:15	83.8	0	23.3	18.2	23	18.4	23.4	23.1	23.1
7/13/2018 8:00	83.8	0	22.2	17.6	22.9	17.5	23.2	22.9	22.9
6/7/2018 11:00	83.7	0	22.5	18	22.6	18.3	23.4	22.8	22.8
6/11/2018 12:45	83.7	0	23.8	19	23.9	19.3	25.1	23.9	23.9
7/12/2018 8:30	83.7	0	23.3	20	23.1	20.2	23.4	23.3	23.3
7/13/2018 9:15	83.7	0	23.3	18.5	23.4	19.1	24	23.2	23.2
7/13/2018 9:30	83.7	0	23.5	18.4	23.4	19.1	24	23.2	23.2
7/13/2018 9:45	83.7	0	23.6	18.5	23.2	19	23.2	23.2	23.2
7/16/2018 19:00	83.7	0	21.9	18.6	23	19.1	23.2	23.2	23.2
7/17/2018 7:45	83.7	0	21.1	17.5	22.7	17.3	22.9	22.7	22.7
7/17/2018 9:45	83.7	0	22.5	17.9	22.9	18.6	23	22.9	22.9
7/17/2018 10:00	83.7	0	22.8	18	22.9	18.8	23	22.9	22.9
6/4/2018 10:30	83.6	0	21.1	16.4	22.9	17.1	23.4	23.2	23.2
6/6/2018 19:00	83.6	0	21.1	19.3	22.8	19.3	23.5	23.1	23.1
6/11/2018 11:30	83.6	0	22.4	17.1	23.1	17.6	23.5	23.3	23.3
7/11/2018 8:30	83.6	0	23.4	19.3	23.1	19.4	23.5	23.3	23.3
7/12/2018 8:00	83.6	0	23.3	17.9	23.1	17.8	23.4	23.2	23.2
7/16/2018 19:30	83.6	0	21.6	19.2	23.4	20.6	23.3	23.2	23.2
7/17/2018 9:30	83.6	0	22.2	17.8	23	18.4	23.3	22.9	22.9
7/17/2018 10:15	83.6	0	22.9	18.1	22.9	18.8	23	22.9	22.9
7/21/2018 9:45	83.6	0	22.1	17.2	23.1	17.4	23.3	23.3	23.3
8/31/2018 9:45	83.6	0	20.7	18	22.5	18.4	23.1	22.2	22.2
5/29/2018 10:00	83.5	0	20.5	16.9	22.7	17.3	23.1	23.1	23.1
6/4/2018 14:15	83.5	0	21.5	18.5	23.8	19.1	25	23.9	23.9
6/6/2018 19:15	83.5	0	21	19.4	22.8	19.5	23.5	22.8	22.8
6/6/2018 19:30	83.5	0	20.8	19.7	22.8	20.7	23.4	22.6	22.6
6/11/2018 13:30	83.5	0	23.9	18.7	23.8	19.4	25	23.7	23.7



Source: Polito Data Lab, 2018

7/11/2018 8:00	83.4	0	23.4	17.5	23.2	17.7	23.5	23.3	23.3
7/13/2018 7:45	83.4	0	22.3	18	23.3	18.1	23.4	23.3	23.3
7/21/2018 10:00	83.4	0	22.4	17.5	23.2	17.4	23.4	23.3	23.3
8/31/2018 9:30	83.4	0	20.6	17.8	22.5	17.9	23.1	22.2	22.2
5/29/2018 9:30	83.3	0	20.3	17.4	22.8	17.4	23.1	23.1	23.1
5/29/2018 9:45	83.3	0	20.6	17.5	22.8	17.4	23.1	23.1	23.1
5/29/2018 12:00	83.3	0	21.6	17.3	23.1	17.2	24.5	23.1	23.1
5/29/2018 12:30	83.3	0	22	17.3	23.5	17.2	24.6	23.4	23.4
5/29/2018 12:45	83.3	0	22.2	17.3	23.5	17.2	24.6	23.4	23.4
6/5/2018 9:45	83.3	0	21.4	17.6	22.2	17.9	23.1	22.2	22.2
6/6/2018 18:45	83.3	0	21.4	19.6	22.9	19.4	23.5	23.3	23.3
6/11/2018 13:00	83.3	0	24	19	24	19.4	25.2	24.2	24.2
6/11/2018 13:15	83.3	0	24	18.7	24	19.4	25.1	24	24
7/21/2018 9:15	83.3	0	21.8	16.7	22.8	17.4	23.2	22.8	22.8
8/31/2018 9:15	83.3	0	20.7	17.9	22.5	18.1	23.1	22.4	22.4
8/31/2018 10:00	83.3	0	20.8	18.7	22.5	19.1	23.2	22.2	22.2
5/29/2018 12:15	83.2	0	21.9	17.3	23.3	17.2	24.6	23.2	23.2
5/29/2018 13:00	83.2	0	22.5	17.3	23.5	17.2	24.7	23.5	23.5
5/30/2018 16:30	83.2	0	19.5	18	22.4	18.4	23.1	22.5	22.5
7/3/2018 9:00	83.2	0	23.5	17.7	23	17.6	23.3	23.2	23.2
7/5/2018 8:45	83.2	0	22.9	17.4	22.9	17.4	23.3	23	23
7/12/2018 7:45	83.2	0	23.4	17.7	23.6	17.6	24	23.5	23.5
7/13/2018 10:15	83.2	0	24.2	19.7	23.3	19.8	24	23.2	23.2
7/17/2018 9:15	83.2	0	22.1	18.3	23.1	18.9	23.9	22.9	22.9
7/28/2018 9:00	83.2	0	24.9	19.4	23.6	19.6	23.6	23.6	23.6
9/22/2018 8:30	83.2	0	21.9	17.4	22.4	17.7	22.6	22.5	22.5
6/7/2018 10:30	83.1	0	22.2	16.7	22.7	17.6	23.5	22.8	22.8
6/11/2018 13:45	83.1	0	24.6	19	24.1	19.4	25.3	24.4	24.4
7/3/2018 9:15	83.1	0	23.7	17.9	23	17.9	23.4	23.1	23.1
7/3/2018 9:45	83.1	0	23.8	18.4	22.8	19	23.3	22.8	22.8
7/6/2018 8:15	83.1	0	23.1	17.3	23.5	17.5	24.5	23.4	23.4
7/6/2018 8:30	83.1	0	23.3	17.5	23.8	17.4	24.8	23.7	23.7
7/6/2018 8:45	83.1	0	23.6	17.6	24	17.4	24.9	24	24
7/21/2018 9:00	83.1	0	21.7	16.8	22.9	17.4	23.3	23	23
8/31/2018 9:00	83.1	0	20.6	17.9	22.6	17.9	23.1	22.4	22.4
9/14/2018 8:15	83.1	0	22.1	19.4	22.9	19.6	23.1	22.9	22.9
5/29/2018 13:15	83	0	22.6	17.3	23.5	17.2	24.6	23.3	23.3
6/4/2018 10:15	83	0	21.2	16.3	23	17	23.4	23.3	23.3
6/5/2018 9:30	83	0	21.3	16.3	22.5	17	23.1	22.5	22.5
6/11/2018 11:15	83	0	22.5	17.3	23.4	17.6	23.8	23.4	23.4
7/5/2018 9:00	83	0	22.9	18	22.8	18.2	23.2	22.8	22.8
7/6/2018 8:00	83	0	22.8	17.1	23.2	17.5	23.4	23.3	23.3
7/10/2018 8:15	83	0	24.2	19.1	23.5	19.4	23.6	23.6	23.6
7/11/2018 7:45	83	0	23.4	17.4	23.8	17.7	24.2	23.6	23.6
7/17/2018 10:30	83	0	23.2	18.4	22.9	18.8	23.1	22.9	22.9
7/21/2018 8:45	83	0	21.7	17	23.2	17.5	23.3	23.3	23.3
8/31/2018 8:15	83	0	22.1	17.8	22.8	17.7	23.2	22.8	22.8
9/14/2018 8:00	83	0	22.1	18.6	22.9	18.9	23.1	22.9	22.9
5/30/2018 13:00	82.9	0	22.4	17.3	23.2	17.3	24.2	23.2	23.2
5/31/2018 13:30	82.9	0	22.9	17.4	22.6	17.5	23	23	23
7/3/2018 8:45	82.9	0	23.5	17.6	23.1	17.5	23.4	23.2	23.2
7/3/2018 9:30	82.9	0	23.8	18	23	18.2	23.4	23	23
7/12/2018 10:30	82.9	0	24.3	19.2	23.8	19.3	24.6	23.6	23.6
7/13/2018 10:30	82.9	0	24.5	19.9	23.4	20.4	24.5	23.2	23.2
7/17/2018 8:30	82.9	0	21.4	19.3	22.4	19.1	22.8	22.5	22.5
7/21/2018 10:15	82.9	0	22.7	17.5	23.3	17.4	23.6	23.3	23.3
9/17/2018 13:00	82.9	0	22.6	20.2	23.2	20.6	24	22.8	22.8
5/29/2018 10:45	82.8	0	20.8	18.1	22.7	18.9	23.1	23.1	23.1
5/29/2018 11:00	82.8	0	21.1	17.6	22.8	17.7	23.4	23.1	23.1
5/30/2018 16:15	82.8	0	21.2	17	22.9	17.3	23.2	23.1	23.1
6/6/2018 16:00	82.8	0	24.6	17.9	23.7	17.9	24.2	23.6	23.6
6/6/2018 18:30	82.8	0	21.8	19.7	22.9	19.7	23.5	23.3	23.3
7/3/2018 8:30	82.8	0	23.4	17.5	23.2	17.5	23.4	23.3	23.3
7/5/2018 8:30	82.8	0	22.7	17.3	23	17.4	23.3	23.1	23.1
7/10/2018 8:00	82.8	0	24.2	18.2	23.5	18.1	23.6	23.6	23.6
7/12/2018 10:15	82.8	0	24.3	19.1	23.9	19.3	24.9	23.7	23.7
7/21/2018 10:30	82.8	0	22.8	17.6	23.3	17.4	23.5	23.3	23.3
9/17/2018 12:45	82.8	0	22.7	20.2	23.3	20.6	24.2	22.9	22.9
9/17/2018 13:15	82.8	0	22.7	20.3	23.2	20.6	24	22.8	22.8
5/29/2018 13:30	82.7	0	22.5	17.2	23.2	17.2	24.3	23.1	23.1
5/30/2018 13:15	82.7	0	22.3	17.3	22.9	17.3	23.2	23.2	23.2
6/4/2018 14:30	82.7	0	21.7	18.9	24	19.2	25	24.2	24.2
7/3/2018 8:15	82.7	0	23.3	17.5	23.4	17.5	23.7	23.5	23.5
7/5/2018 8:15	82.7	0	22.5	17.4	23.2	17.5	23.4	23.3	23.3
7/6/2018 9:00	82.7	0	23.9	17.5	24	17.4	24.9	24.2	24.2
7/6/2018 9:30	82.7	0	24.3	17.4	24	17.4	24.9	24.1	24.1
7/12/2018 10:00	82.7	0	24.3	19.3	24	19.3	25	23.9	23.9
7/12/2018 19:15	82.7	0	23.7	19.9	23.8	20.4	24.1	23.5	23.5
7/13/2018 10:45	82.7	0	24.7	20.2	23.6	20.8	24.7	23.3	23.3
8/31/2018 8:30	82.7	0	21.8	18.1	22.8	18.5	23.2	22.8	22.8

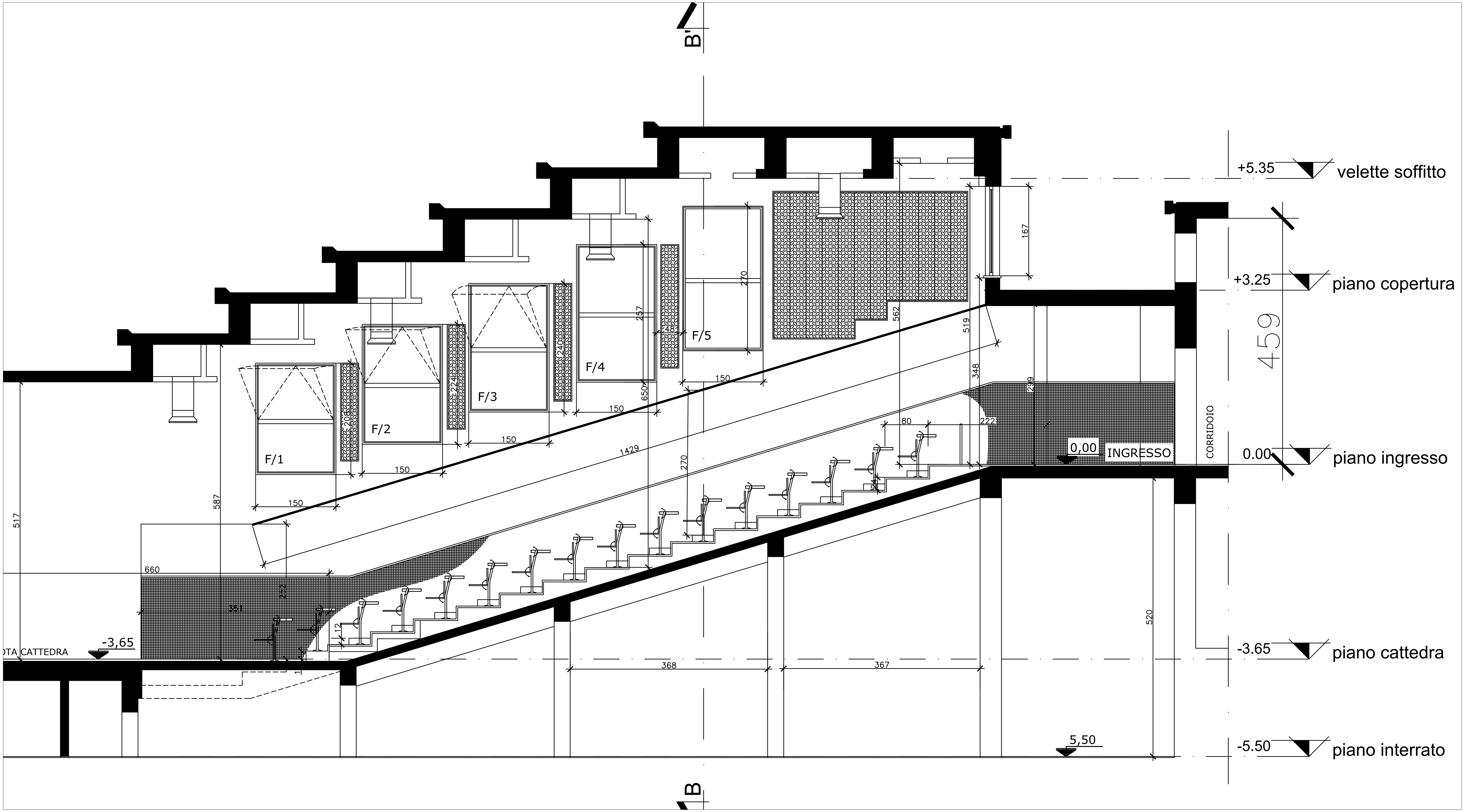
5/29/2018 13:45	82.6	0	22.8	17.2	23.2	17.2
5/31/2018 13:15	82.6	0	22.7	16.8	22.7	17.4
6/11/2018 14:00	82.6	0	25.1	18.7	24.3	19.4
6/11/2018 14:15	82.6	0	24.9	18.3	24.3	18.6
7/3/2018 8:00	82.6	0	23.2	17.7	23.7	17.6
7/5/2018 8:00	82.6	0	22.5	17.6	23.4	17.5
7/6/2018 9:15	82.6	0	24.1	17.3	24	17.4
7/11/2018 8:45	82.6	0	23.5	20.1	23.3	20.3
7/20/2018 8:15	82.6	0	24.5	18.6	23.6	19
7/21/2018 10:45	82.6	0	23.1	17.7	23.3	17.6
7/21/2018 11:00	82.6	0	23.4	18.1	23.3	18.5
5/30/2018 12:45	82.5	0	22.4	17	23.3	17.3
5/30/2018 18:30	82.5	0	21	19.7	22.4	20.1
6/7/2018 11:15	82.5	0	22.7	19	22.9	19.3
7/5/2018 9:15	82.5	0	23	19	22.8	19.2
7/12/2018 10:45	82.5	0	24.4	19.5	23.8	19.3
7/13/2018 11:00	82.5	0	24.8	20.3	23.6	20.9
7/16/2018 18:30	82.5	0	21.8	18.1	23.5	18.4
7/21/2018 8:30	82.5	0	21.7	17.4	23.5	17.5
8/31/2018 8:00	82.5	0	22.3	17.5	23	17.6
9/24/2018 8:00	82.5	0	21.6	19.2	22.6	19.4
6/11/2018 14:30	82.4	0	25	18.1	24.2	18.1
6/11/2018 14:45	82.4	0	25.6	18.4	24.1	19
6/22/2018 8:15	82.4	0	24.4	18.5	23.7	18.9
7/3/2018 10:00	82.4	0	24	19.5	22.9	19.6
7/6/2018 9:45	82.4	0	24.4	17.5	24.1	17.3
7/12/2018 8:45	82.4	0	23.5	20.9	23.4	21
7/12/2018 19:00	82.4	0	23.9	20	23.9	19.8
7/12/2018 19:30	82.4	0	23.4	20.5	24	21.1
7/13/2018 7:30	82.4	0	22.6	18.9	23.9	19.3
7/16/2018 8:00	82.4	0	23.4	18.1	23.1	18.7
7/20/2018 9:30	82.4	0	25.5	18.2	24.3	18.8
7/20/2018 10:15	82.4	0	25.6	19	24.1	19.1
7/28/2018 8:45	82.4	0	24.9	18.8	23.8	19.5
9/17/2018 12:30	82.4	0	22.8	20.2	23.3	20.6
6/11/2018 11:00	82.3	0	22.8	17.9	23.7	17.9
7/3/2018 7:45	82.3	0	23.3	17.9	24	17.8
7/6/2018 7:45	82.3	0	22.9	17.2	23.5	17.6
7/6/2018 10:00	82.3	0	24.6	17.3	24	17.3
7/12/2018 9:45	82.3	0	24.2	19.8	24	19.7
7/13/2018 11:15	82.3	0	24.9	20.4	23.7	20.9
7/16/2018 7:45	82.3	0	23.3	17.6	23.4	17.5
7/17/2018 10:45	82.3	0	23.5	18.6	23	18.8
7/20/2018 8:00	82.3	0	24.5	17.7	23.8	17.6
7/20/2018 9:45	82.3	0	25.5	18	24.2	18.5
9/14/2018 7:45	82.3	0	22.1	18.3	23.2	19
5/29/2018 14:00	82.2	0	23	17.2	23.2	17.2
6/7/2018 18:45	82.2	0	20.3	17.6	22.9	18
7/4/2018 8:00	82.2	0	23.2	17.1	23.2	17.5
7/14/2018 8:45	82.2	0	24.3	19.2	23.2	19.5



Source: Area Edilog, Polythechnic University of Turin, October 2019

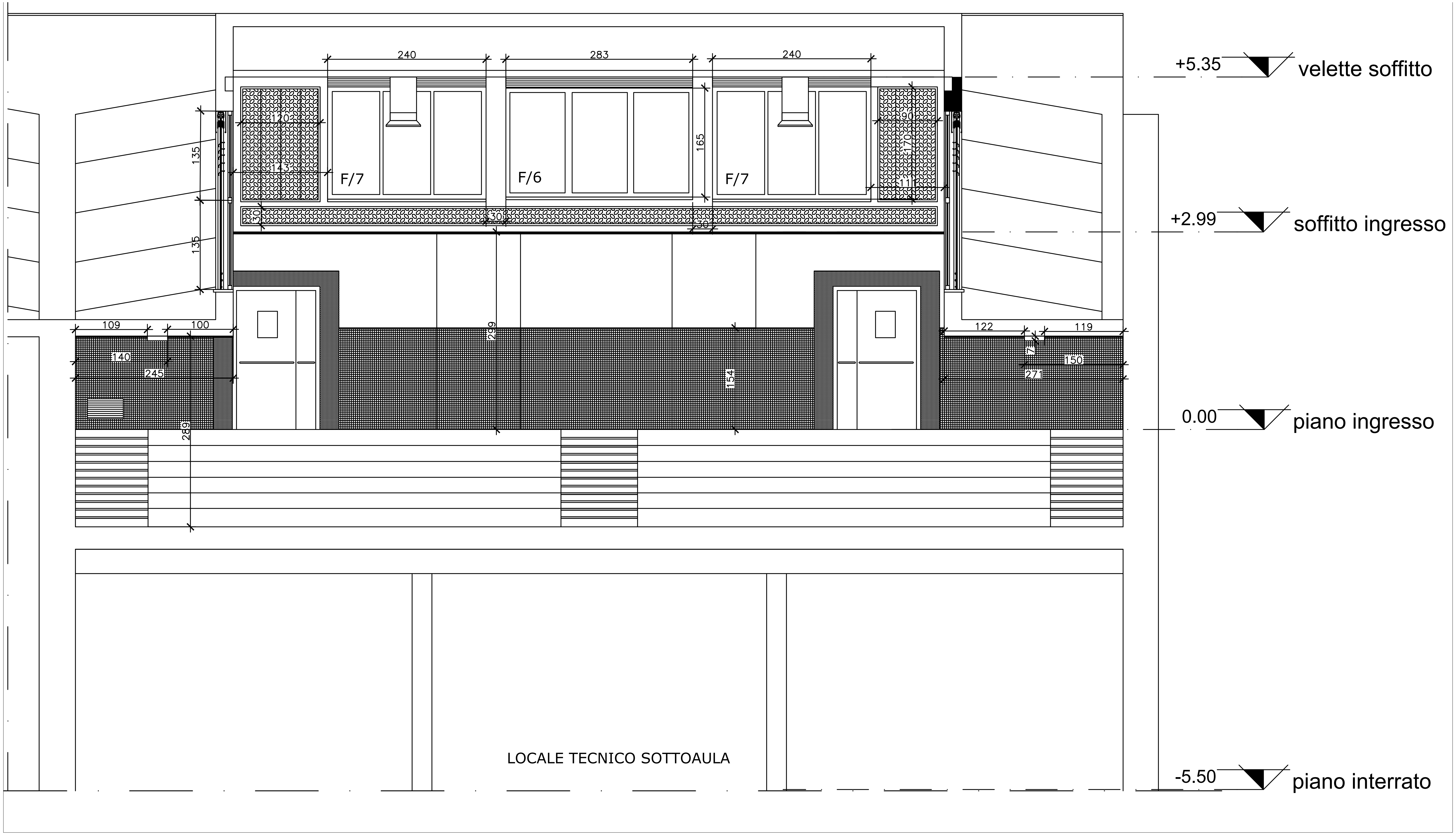
Scale: 1/50

SECTION A-A'



Source: Area Edilog, Polythechnic University of Turin, October 2019

Scale: 1/50



Source: Area Edilog, Polythechnic University of Turin, October 2019

Scale: 1/50