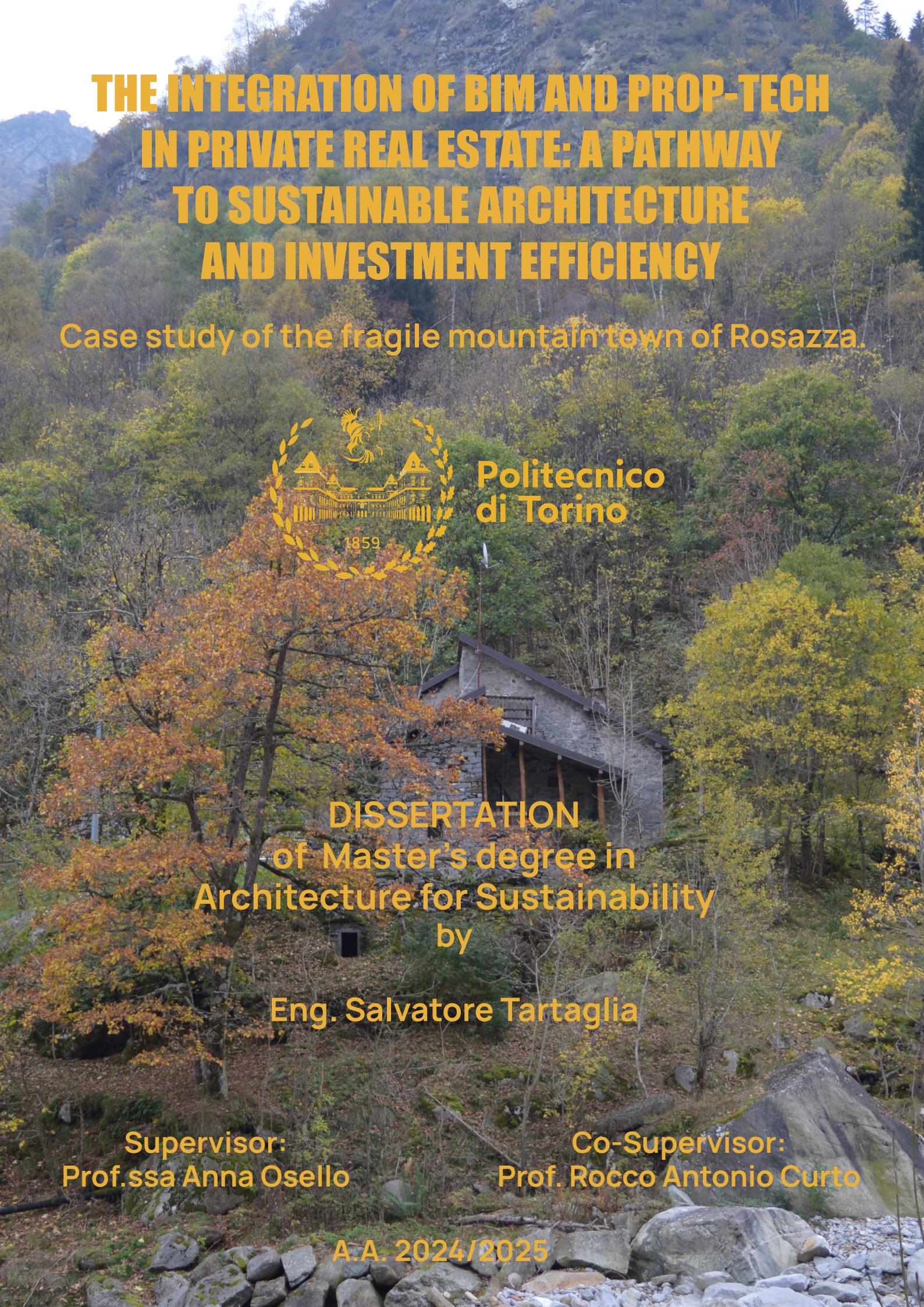
THE INTEGRATION OF BIM AND PROP-TECH IN PRIVATE REAL ESTATE: A PATHWAY TO SUSTAINABLE ARCHITECTURE AND INVESTMENT EFFICIENCY

Case study of the fragile mountain town of Rosazza.



Politecnico di Torino

DISSERTATION
of Master's degree in
Architecture for Sustainability
by

Eng. Salvatore Tartaglia

Supervisor:
Prof.ssa Anna Osello

Co-Supervisor:
Prof. Rocco Antonio Curto

A.A. 2024/2025

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ABSTRACT

The aim of this thesis in architecture for sustainability is to propose a BIM-based method that can be integrated with other disciplines according to a multi-level approach to design (Whole Building Design) and capable of involving various specialists (structural engineers, energy experts, restorers, economists, etc.), who must share economic optimisation objectives together with the constraints of preserving assets of historical, architectural and environmental interest.

The method is based on the use of BIM and technologies such as GIS, Digital Twin and IFC interoperability to simulate design alternatives according to costs and different usage or investment requirements on multiple scales. The thesis explores the potential of BIM in connecting specialists and supporting intervention decisions, considering economic and financial feasibility in relation to potential buyers interested in use and/or investment value.

Particular attention is paid to PropTech technologies, as tools capable of optimising the processes of restoration, energy retrofitting of the building heritage, promoting private initiatives and the revitalisation of fragile villages subject to depopulation, with a view to reusing and valorising mountain architecture and improving quality of life.

The case study focuses on the potential regeneration of the historic village of Rosazza, one of Italy's most beautiful villages, but subject to abandonment, depopulation and a lack of services. The proposed method involves three levels of scalability, and the thesis focuses on the first. In each case, the objective remains to optimise costs, quality and economic values, in line with the logic of project/construction management for simulation even in different contexts.

The first level demonstrates the transferability of the method to all mountain villages similar to Rosazza in terms of architectural characteristics, population and services, aiming to optimise interventions also with regard to potential new needs related to the use of the mountains.
The second level concerns the transferability of the method to villages in fragile areas, such as inland plains and suburban neighbourhoods excluded from urban development dynamics, making assets accessible even to marginal areas with low solvency thresholds.
The third level proposes the adaptation of the method to large projects, according to a logic of investment in dynamic markets.

The digitisation of the village exploits IFC interoperability between GIS and BIM. After creating a BIM urban model of Rosazza, as a prerequisite for a future Digital Twin, the project is further developed at the building scale with a BIM model with a higher LOD, used to test the proposed method.

The building intervention focuses on conservative restoration in compliance with restrictions, the drafting of a bill of quantities of an optimised meta-design hypothesis in a BIM environment, and the analysis of variables in the specifications related to alternative design solutions. The cost analysis is then integrated with the financial analysis of the investment, evaluating scenarios for residential, temporary and tourist-accommodation sales and rentals. Having verified that the most favourable scenario is temporary rental, the thesis returns to the territorial scale, outlining future scenarios for smart cities and real estate investments in abandoned villages and beyond, with the potential to also compete in national or European calls for inland areas.

Salvatore Tartaglia

«Mi trovai in una casa che non conoscevo.
Andavo da una stanza all'altra esaminandole.
Tutto era antico, del Settecento… Scoprii poi una scala di pietra che conduceva a una cantina… C'era una seconda cantina più profonda, risalente al Medioevo, e sotto ancora una cantina di epoca romana…
In fondo trovai resti di un'abitazione primitiva.»

…

«Compresi allora che quella casa era l'immagine della psiche, una sorta di diagramma della struttura della mente umana.»

C.G. Jung, Memories, Dreams, Reflections,
1965, pp. 158–160.

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View of Rosazza. By Salvatore Tartaglia

PREFACE

This spark of this thesis was born from my interest in sustainable architecture and the idea of restoring the built environment with attention to revitalize fragile or semi-abandoned areas, focusing on the energy transition towards more efficient buildings and the growing interest for the brunch of sustainable real estate.
The village of Rosazza, with its unique architectural heritage offers a good case study to explore. Specifically it is studied how the preservation of the built environment and the technological innovation can coexist and create opportunities for the sustainable environmental, social and economical development.
Traditions and Modernity, Preservation and Innovation.
This is the binomial that put together the effort of this master's degree thesis.
The restoration of the mountain town with the BIM and PropTech technology may become an example for other realities in similar or different conditions.
Approaching the preservation of the fragile town represents both an evironmental and architectural challenge, that need to be faced in order to not lose part of the historical heritage and identity of Italy.
In this way BIM can contribute as a methodology and a "tool" for simulations of projects and costs, to relate to the economical and financial feasibility of the private interventions, with the final goal of minimizing the ratio among costs/quality that should be a pre-requirement for social and sustainable architectures.
The research was carried out within the framework of the Master's Degree in Architecture for Sustainability, at Polytechnic University of Turin.

Drone view of Rosazza. By @epikdrone Frik Alvarez

INTRODUCTION

VDC (Virtual Design and Construction) in Architecture

Mountainous areas like Rosazza pose unique challenges as well as opportunities for sustainable development. Their steep landscapes, shifting climates, and relative isolation demand innovative design and construction strategies that can withstand harsh environmental conditions while preserving fragile ecosystems. Among the fragile areas, mountain areas "with a height above 600 m above sea level are connected to geomorphological fragility and poor accessibility, which have determined, in many areas, conditions of economic impoverishment with consequent significant depopulation", "the element that appears decisive in the destiny of mountain areas, however, is the number and quality of infrastructures. Think of transport, logistics, essential public works" [1]. At the same time, many of these regions represent a native environment to communities with deep historical roots and architectural traditions, requiring modernization efforts to be both respectful and energy-conscious. In this context, BIM plays a crucial role, providing accurate modelling, real-time data integration, and collaborative project management tools that improve both the sustainability and efficiency of construction initiatives.

Town Hall of Rosazza and Via Roma. By Salvatore Tartaglia

STATE OF THE ART

1

BIM, property technology and the optimization of the real estate sector.

Over the past few decades, the design and construction sectors have experienced the adoption of more updated and efficient digital solutions, which allowed an overall improvement in the acquisition and transformation of the built environment, especially in the architectural and engineering fields. Nowadays, in fact, the use of terms such BIM, Augmented/Mixed/Virtual Reality, Artificial Intelligence, GIS, Digital Twin are some of the most known concepts. The trend is moving towards the combination of these technologies to reach very significant improvements in all the faces of the design and construction sectors. In particular, the past three decades the building information modelling for instance, revolutionised the construction sector in terms of efficiency in the preparation and the deliver of the projects and also in their quality. On the other hand, it is not possible to ignore the tremendous amount of BIM software that have been released in a short time, which also contributed to a difficult management of the software licences and some issues of interoperability among software [2].
The combination of these technologies can contribute to the development of good quality architectural project and can optimize at the same time the real estate sector with a more efficient data management and more accurate economical and financial analyses.

Chalet in Rosazza. By Salvatore Tartaglia

CASE STUDY:
Rosazza, Italy.

2

Silent Treasures: Unveiling the Value of a Forgotten Place

The area of Valle Cervo in the province of Biella (Italy), is a mountain territory that follows the direction of Cervo torrent and includes 13 towns, among them Rosazza, Piedicavallo, Pralungo et cetera. The area was crucial in the historic for its strategic position in the limit between Italy and France, for migration aspects. The valley part of Valle Cervo has an extension of around 73 km^2 and starts from the strettoia (narrow street) of Bogna until the arch of the Pennine Alpes, with the peak point in the cima Bo (2556 meters).

During the history different populations established in the area of Monte Cervo and in Rosazza. Among them, the Celtic and Mediterranean populations.

Rosazza takes its name from Rua (roggia), or Rusascia, that represents the river that flows at the base of the village Borgo and Cervo. In the area of intersection between the two rivers there is the town of Rosazza, which is linked to the water of the river and the stone, as a traditional material for construction. The distance between the metropolitan city of Torino and Rosazza is around 95 km by car, while the distance from Biella is about 15 km. Rosazza was under the municipal control of Vercelli until the 1992 and then it became part of the control of the province of Biella.

During the history, in the end of the XIXth century, Rosazza became famous for the visionary architectural project sponsored by a famous and rich citizen whose name is Federico Rosazza Pistolet, born in Rosazza, to whom the town took its name. New building and infrastructures have been built and the peculiar of these interventions was the use of freemasonry and occultism motifs. The politician used to share the same interest with the artist Giuseppe Maffei who contributed to realizing the project.

The esoteric atmosphere reigns in the town, which has strong medieval features, providing the definition as the most mysterious town in Italy.

Visiting the town means exploring a rare environment.

The atmosphere of silence disturbed only by the sound of the river and of the animals, the peace far from the chaos of the cities, creates a mysterious place where everything seems frozen in time.

Monumental Cemetery of Rosazza. By Salvatore Tartaglia

BETWEEN FREEMASONRY AND MYSTICISM: ESOTERIC SYMBOLISM IN ROSAZZA'S ARCHITECTURE

2.1

Rosazza is a location where history and intrigue meet together. Named in honor of the 19th-century senator and philanthropist Federico Rosazza Pistolet, an important figure in the Italian unification effort and associated with Freemasonry, the village is deeply permeated of a mysterious atmosphere. The Freemasonry had a central role during the Italian Risorgimento, an historical period during which Italy reached the full national unity (1815–1871) and the 19th-century campaign for Italian unification, where he significantly contributed to the emergence and initial growth of the new nation: it was during this period of time that Rosazza Pistolet was involved in the policy and the commission of architectural projects and urban interventions in the town. During his long life, Federico Rosazza Pistolet suffered two tragic events: the death of his wife and that of his daughter. Probably the sufferance caused by the two tragic events pushed him to explore the values of the occult, with his loyal companion Giuseppe Maffei, trying to find answers and support [01]. The Parish Church was dedicated to Saints George and Peter, is as a symbol of cultural and historical importance. It was planned in 1876 and finished four years after, following the ideas and the designs of Giuseppe Maffei. It was constructed on the site of an ancient graveyard and showcases a Gothic arch on its front, embellished with many roses. The cemetery has a monumental importance and it is deeply characterized by esoteric symbols and mysterious atmosphere. Also the bridge that connects the cemetery on the other side of the river to the rest of the town presents several symbols and marks. In addition to this, "Rosazza Pistolet's vision extended to the very layout of the village. The streets, aligned with astrological significance, and buildings designed according to Masonic principles, make the village a living canvas of his inner world. Streets here are lined with unique stone fountains, each distinct yet unified by the recurring motifs of the rose and the five-pointed star, symbols deeply rooted in Masonic tradition" [2].

Moreover, the presence of the swastika cross connected to the Gallic cult of female fertility, the "Door of the Righteous" and the ceiling painted with a starry sky. It is said that here the senator would contact various spirit guides during mysterious rituals [3].

Federico Rosazza commissioned also the construction of several stone fountains in with particular and mysterious symbols and messages written on top, as can be seen in the following pictures. The collaboration between senator Rosazza and architect Giuseppe Maffei was essential to characterize the final atmosphere of the town.

Abacus of Esoteric Language


Sculpture decoration in a fountain


Hourglass symbol in the bridge


Star symbol in the bridge


Star symbol in the wall


Decorated stone manhole


Stone fountain with figures


Painting of a man with a sheep


Swastika cross in the wall

Decorated column

Photos by Salvatore Tartaglia

Statue of a sad woman.
By Salvatore Tartaglia

BIODIVERSITY CONDITIONS 2.2

The area of Rosazza is very rich of forests of beech, chestnut trees, oaks (quercus), Norway spruce and conifers in general. The soil is very rich, and the lawn is full of different species of flowers, shrubs. In the rivers close to Rosazza some species are presents: caddisflies, mayflies and stoneflies, that are an indicator of good quality of the water. In the case of mammals and animals in general, there are several species present in the area, such as the deer (cervus elaphus), the roe deer (capreolus capreolus), the European lynx (lynx lynx), the occasional brown bear (ursus arctos), wild boar (sus scrofa), or the fox, badger, marten, wild boar, marmot, hare, ermine, dormouse, and marten. In the case of the birds, such as the eagle (aquila chrysaetos), the falcon, alpine chough. Reptiles such as viper (vipera berus), amphibians, alpine newt, common frog are also presents [5]. An effort to keep the natural conditions not altered by human activity is crucial for maintaining the existing biodiversity and attracting non native species that can integrate in the context and preventing the appearance of alien species, due to climate change and environmental modifications, because they can damage the other biodiversity of Rosazza and destroying the population of other insects and animals.

The following abacus gives more in deep informations regarding the biodiversity of Rosazza.

The plants reported are only some of the big variety of species that can be found in the town and in Valle Cervo, such as: mountain maple, alpine columbine artemisia, hybrid aspsenium, alpine astro, birch, buddleja, hornbeam, chestnut, biella cornflower, crocus, spurge, heather, beech, fern, blueberry, narcissus, hazel, alder, dwarf rapunzel, primrose, rhododendron, wild rose, edelweiss, armillaria tabescens, goji berries, acer rubrum, thysselinum palustre, lamium maculatum etc. Among all the trees, the chestnut has a special value, in fact during the 19th century, the significance of chestnut farming for social and economic reasons decreased in both Italy and Piedmont. This was primarily due to the swift desertion of regional mountain communities and alterations in dietary habits. Due to these factors, numerous locations, previously defined by the existence of chestnut trees, having lost their form and sense of self. [6]

Additionally, the neglect resulted in a significant decline in biodiversity and traditions. and cultural legacy. In Piedmont, the assessment of the comparative pH level of the soil [7]. Initiatives of conservation prioritize safeguarding habitats against non native and damaging species and support sustainable practices to preserve biodiversity and ecosystem balance.

Abacus of Biodiversity


Betula pendula (local)


Fagus sylvatica (local)


Picea abies (local)


Rosa canina (local)


Dryopteris affinis (local)


Armillaria tabescens (local)


Lamium maculatum (local)


Thysselinum palustre (local)


Acer rubrum (unlocal)

Photos by Salvatore Tartaglia

ENVIRONMENTAL CONDITIONS AND RISKS 2.3

Rosazza has a mountain territory with an average altitude equal to 882 meters with a minimum of 849 m and a peak of 2167 m (its latitude is 45° 40' 36,12" N 45,6767° N and longitude 7° 58' 41,52" E 7,9782° E). The main threat for Rosazza and Valle Cervo is the floods of the rivers, expecially *Torrente Cervo*. In fact, as reported by Alberto Rosazza, a local resident of Rosazza who told that in 2020 the flood destroyed 5 bridges that have been rebuilt and "took away" around 50 meters of ground close to the steel bridge of Rosazza: "each 20 years a flood happens, the first one was in 1981, then 2002 and 2020, that was the worst one", "when I was a child this torrent was 6 meters wide and I used to go fishing...now it is 100 meters". There is also another general environmental problem in Rosazza that is represented by the floods. The first one that has been reported was the one of 1666 in which the flooding of the Cervo River destroyed twenty houses, but without any death. Alberto Rosazza refers that: "in the past the bura (the torrent in the local dialect) flooded two times a year (overflows), in May-June and October-November but it was raining 1 week-10 days, nowadays in only two hours that amount of water arrives" and regarding the temperature he refers that: "the climate changed, because we used to have the snow here, nowadays we spend Christmas without the snow. Lately it does not snow anymore, during the Christmas holidays when there was only few snow, in reality it was 1,5 meters high the level of the snow, now the snow is a mirage. Last year at around 2000 meters of height there was a certain amount of snow and here (in Rosazza) we are at a level of around 2500 meter; but this year there is not snow, not an avalanche...in July you normally see the snow in the rivers". Alberto Rosazza refers also that in the past It was frequent to hear the bells in Rosazza and many children used to clean the city under a small economical contribution. Nowadays he continues "this summer we had one day with 30 degrees during the night, something never saw before". In fact, due to the morphology and the proximity to high mountains, exspecially in the period of snow, when a big amount of water is released in the river. The orographic and hydro-graphic characteristics of Rosazza and the slope of its land impacts also in the other towns of Valle Cervo and Biella are occasionally impacted by hydro-geological instability, which takes place during precipitation occurrences of a specific magnitude. Such as in the case of June 2002, when the Biella and all the towns of Valle Cervo experienced serious hydro-meteorological problems that produced an extensive destruction with the release in Piedicavallo of 67,6 mm of rain water in the ground in the first hour and 333,8 mm after 24 hours from the beginning of the catastrophe. Connected to the floods, there is also the problem of the landslides. The landslide occurred in Valle Cervo caused big damages also in Rosazza, where the drainage of water and rough material alongside the town road beneath; the surface water eroded the sidewalk for roughly 200 meters. In 2025 the Piedmont contributed with a percentage of the total investment of 400'000 euros to secure the side of the Cervo Valley, right next to the tunnel entrance, which has been closed also in the summer of 2025. Another environmental threat to consider is represented by the earthquakes. Rosazza is located in an area characterized by a seismic risk equal to 3, whose condition is officially defined as "municipalities in this area may be subject to modest shocks" by the civil protection department of the Italian government. In these terms, the area presents a medium to low seismic risk, with a probability of acceleration of the soil (PGA) in between the values of 0.05g and 0.15g, in other terms, the probability of overcoming some specified values of PGA in a time frame of 50 years in the case of Rosazza with seismic risk=3 is 10%. The seismic risk in Italy, updated in 2009 with the introduction of the NTC08, defined a number of around 1560 towns and cities in Italy with a seismic risk=3 and among them there is Rosazza. Although the risk of earthquakes is high enough if we compare it to other areas of Piedmont or the north of Italy, in some buildings of Rosazza there is the presence of evident cracks in the structural stone masonries, as can be seen in the following picture at page 46. As consequence of this, different buildings have been reinforced thanks to the use of *tie rods* and *chains,* but in other cases the houses with evident cracks are still abandoned today, which means that the risk of collapse of the structure is very high. Despite the presence of the evident cracks and damages in the houses, Rosazza represents an emblematic case of town that survived among the years and kept the historical and original peculiarity of its architecture. It is possible to affirm that the town has remained relatively intact, and the reasons behind this are linked to the great skills and experience of the local workers, who built the house in the 19th century with careful and deep knowledge of the construction techniques. In Rosazza and Valle Cervo in general, an important problem that normally is not enough considered is linked to the presence of radiations and radon. This natural radioactive natural gas is colourless, odourless and tasteless and derives from the decay of uranium. In all the cities the presence of this dangerous component is monitored through specific sensors. For preventing and limit the diffusion and exposition to this gas, that is frequently present in the mines and Valle Cervo is full of mines and places of extraction of rocks, is to allow a circulation of fresh air from the outside of the house and to restore old basements of the houses that are in direct contact with the ground and normally do not have enough fresh air.

DEMOGRAPHIC ANALYSIS 2.4

Rosazza, whose cadastrial code is H561 and ISTAT code 096055, is characterized by a density of inhabitants per km² of: 11,02 inhabitants/km² and the total surface of the town is 8,71 km². Based on the ISTAT informations, the most updated data about the number of the population in the town is 96 inhabitants declared on the 1st of January 2025.

In the years 2024 and 2025 the population reached the number of 96 inhabitants. Among them, the distribution of female and male is shown in the (Figure 6) of the next page. The population pyramid is a graphical method represented like a pyramid, that visualizes a population's age and sex distribution at a specific point in time.

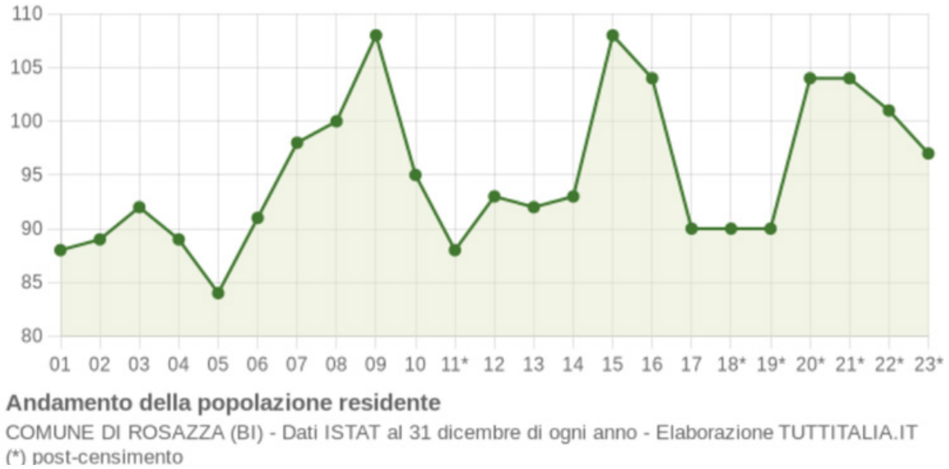


Figure 5: Graph of the trend of the population since 2001 until 2023
https://www.tuttitalia.it/piemonte/26-rosazza/

In the graph starting from 2001 the number of residents is low (around 88), then there is a rapid growth from 2001 to 2009, when the inhabitants were 107. Suddenly a relevant decrease in the population to reach again 88 people in 2011. After 2011, other two peaks, one of 107 and the other of 104. In the last period, that starts from 2020 to 2023, there was a small decrease of the population form 104 to 97. For

In the previous graph the data were collected from the ISTAT website [02], that is a statistic institution that provide all the data regarding the population in Italy, exported and represented in Excel. The data come from the permanent population count, calculates the municipal resident population by gender, year of birth, and marital status as of December 31st of each year and is published on January 1st

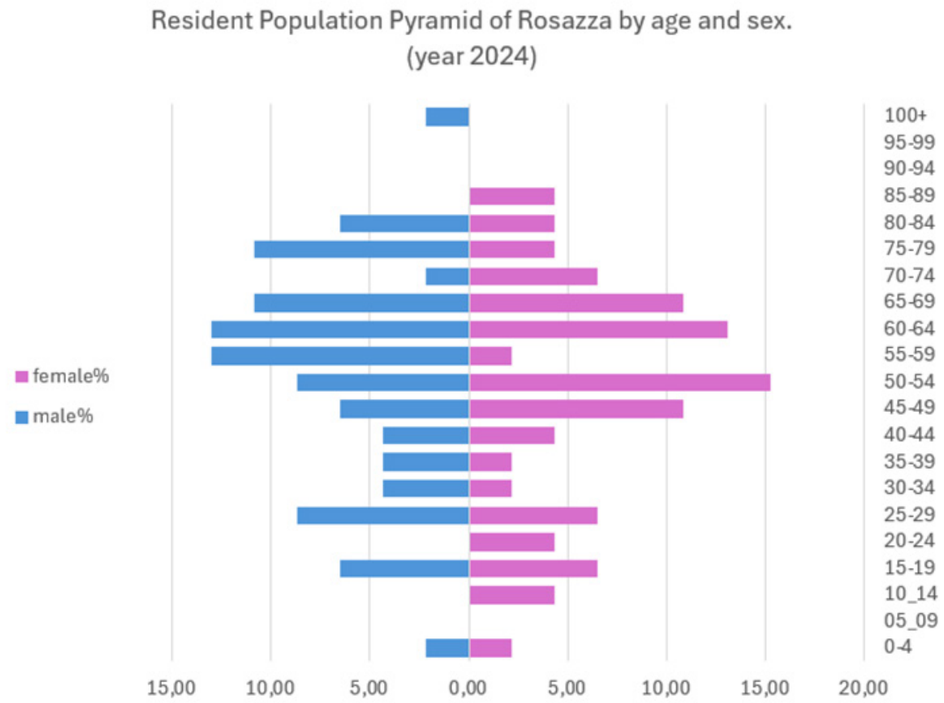


Figure 6: Resident Population Pyramid of Rosazza, data collected by age and sex.
Data collected from ISTAT. (Personal contribution)

of the following year. The resident population consists of people, both Italian and foreigners, who are mainly habitual resident in the country, even if temporarily absent in the town. Overall, despite a small uptick in 2020 that results anomalous considering the rest of the data, the trend of the resident population in Rosazza in the last years shows a small decrease [03]. Because the population numbers are very small, year-to-year fluctuations may be strongly influenced by small numbers of moves or changes (e.g., a few families leaving or arriving) rather than broader structural forces. In general, these data referred to the geographical extension of the territory, show a remarkably low density (≈11 residents per km²), that

indicates an exceedingly spread populated municipality among the lowest in the area. But considering that the decrease follows a trend, It results reasonable to imagine that the situation could get worse and worse with the time also if we take into account that the average age of the residents is considerably high. In fact, it accounts for 53,9 years and at the same time the low share of foreign residents suggest limited inflow of younger or immigrant population to bring to natural decline, that is connected also to the birth rate which is close to zero in most recent years, while the death rate remains high, producing a persistently negative natural balance. Moreover, most employed residents work outside the municipality, primarily in Biella

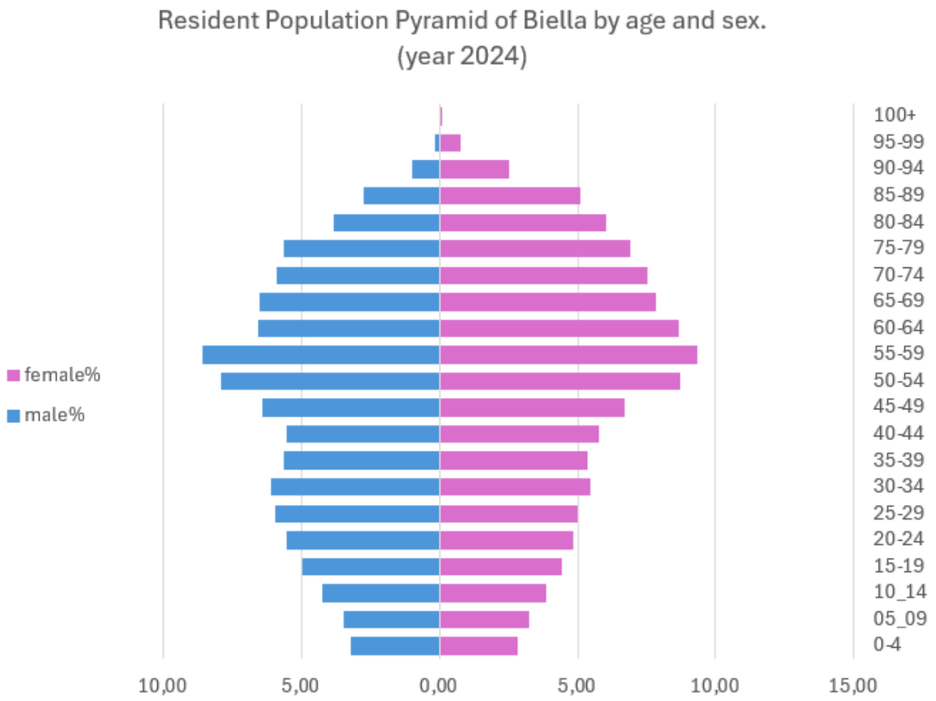


Figure 7: Resident Population Pyramid of Biella, data collected by age and sex. Data collected from ISTAT. (Personal contribution)

or Andorno Micca, indicating high dependence on external job markets and limited local opportunities. From the educational point of view a significant portion of the elderly population has only primary education, while younger residents tend to have higher qualifications but often leave the area for employment opportunities elsewhere, exspecially in Biella and Andorno Micca, respectively distant from Rosazza 8–9 km (15 minutes of car) and 17-18 km (30-35 minutes of car). The resident population of Biella, that is the province of Rosazza for the year 2024 accounted for 42'909 inhabitants. As shown in the upper graph, the resident population distribution by age and sex in Biella (Figure 7).

The demographic analysis of the population of the province of Biella is a key element to consider because it provides the data to understand the potential real estate growth in Rosazza. As a result of the interventions aimed at revaluing of the architectural and environmental heritage of Rosazza, It can become an attractor for people and inhabitants coming from the surrounding towns and especially from the city of Biella which has a relevant number of citizens as shown in the graph.
Furthermore, the study of the demographic structure of Biella and its services system is crucial for understanding the network of facilities and infrastructures that the main city can offer to Rosazza, as well as the connectivity among the two contexts.

2.5 MARGINALITY CONDITIONS IN PIEDMONT AND ITALY: SPATIAL AND ECONOMICAL INEQUALITIES

The marginality of the towns represents a quantitative phenomenon of fragility that cross the entire Italy. In the research contribution: "*La marginalità della montagna italiana e del Piemonte*" made from the results of a collaboration between the Istituto di Ricerche Economiche e Sociali (IRES Piemonte) [8] and the DIST of the Polytechnic and University of Turin, carried out in 2021 by Dr. Alessandro Collet, coordinated by Prof. Federica Corrado and the author, focusing on the marginality of mountain municipalities in Piedmont and across Italy with less than 5000 inhabitants, but the problem is wider and involves also the Italian towns in the seafront and in the valleys. After analysing and assessing the conditions of the most attractive towns, so the 20 municipalities that achieved the highest outcomes, there is a predominance of municipalities in the Turin area (13 of 20). Bardonecchia stands as the first and most honorable and attractive town of Piedmont. They are municipalities with a highly significant commercial and economic structure. Overall, the cities exhibiting the greatest index are extensive metropolitan areas, frequently situated in valley, that host a substantial amount of economic activities (such as Lanzo Torinese and Villar Perosa) or are key tourism hubs in Piedmont (such as Bardonecchia and Sestriere). With regards to the 20 most isolated mountain municipalities, these are very frequently small, low populated areas, marked by a deficiency of economic engagement and commercial land degradation, which also results in an extremely low job availability. Up to 8 of the 20 municipalities are situated in the Apennines or Alta Langa. The town with the least value is Cervatto in Valsesia (VC), as well as Carrega Ligure in the Monti Appennini di Alessandria. Rosazza is classified in the 13th place out of 20 among the most isolated and fragile towns of Piedmont (with an evaluation based on the activity of -0,712 highlighted in red colour in the maps). All the Piedmont municipalities in marginal conditions and with less than 5000 inhabitants have been ranked with an evaluation based on demography, activities, marginality index.

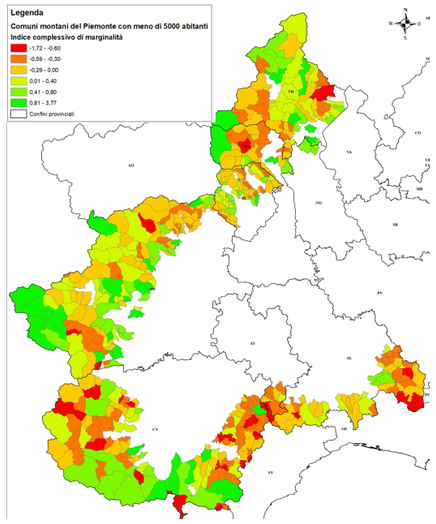


Figure 8: Marginality map of Piedmont

Codice ISTAT	Nome comune	Provincia	Demografia	Reddito	Dotazioni	Attività	Indicatore marginalità	Posizione in graduatoria
96055	Rosazza	BI	0,164	0,406	-0,510	-0,712	**-0,163**	244

Figure 9: Parameters of Rosazza

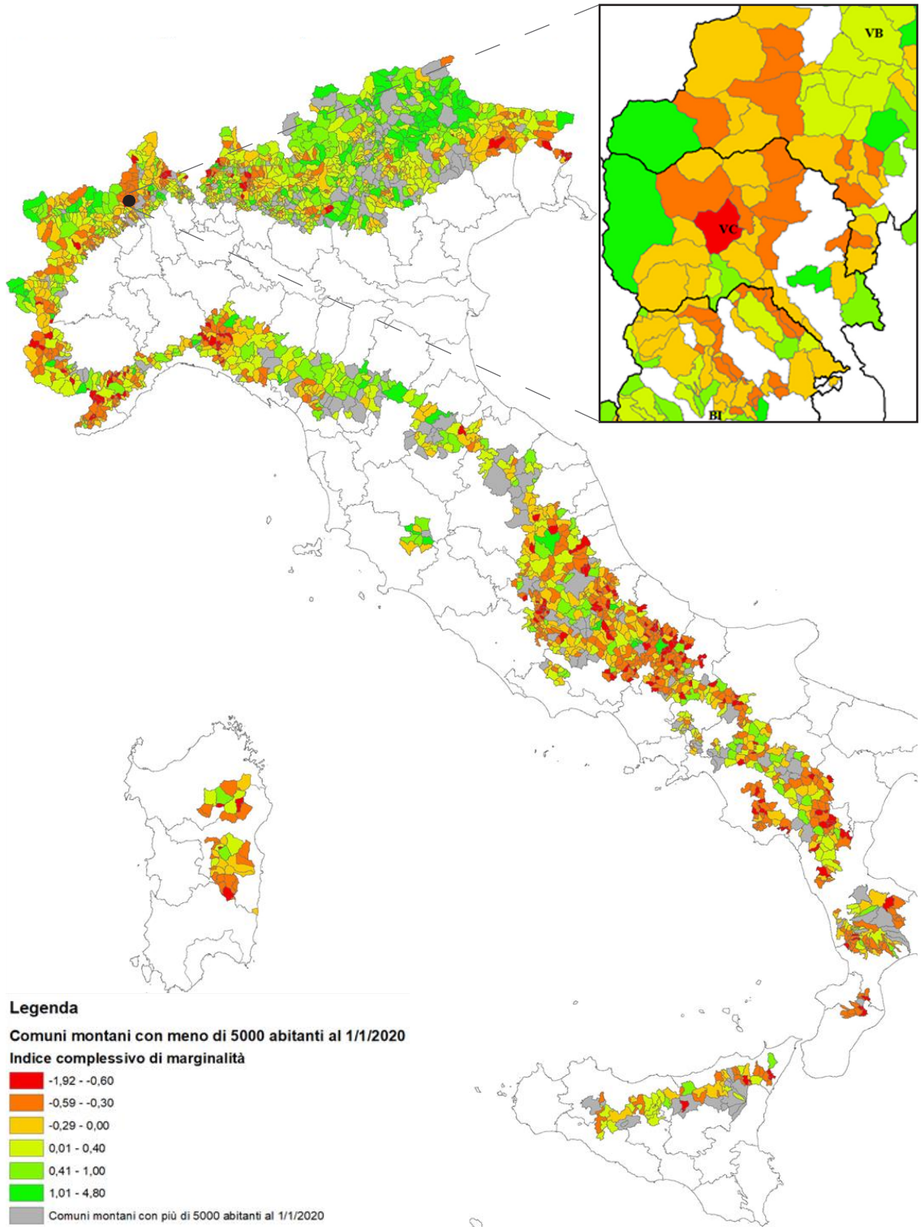


Figure 10: Italian map of the overall margin index (demographics, income, activities and fundings) and detailed map of Rosazza town; from *La marginalità della montagna italiana e del Piemonte*.

ACCESSIBILITY AND REGIONAL CONNECTIONS: INFRASTRUCTURE AND MOBILITY. 2.6

During a site survey made on 19th of October of 2025, some residents of Rosazza and tourists were interviewed in order to get a feedback regarding different aspects analysed in this thesis. Among the questions related to their opinion regarding the evolution of the city in the last years, the environmental conditions, the real estate development in the town, the conditions of the abandon of the houses, they were also interviewed to get some informations regarding the services, commercial activities, connectivity and transportations. The results of the interviews related to these two aspects, highlight an overall necessity to introduce a policy of improvements in the transportation services and to invest in commercial activities that can guarantee at least sufficient food supplies, that specifically in Rosazza are mainly provided by an important bar in Via Roma that is always open, named *La Strettotia* and a small market *La Siunera,* next to it, as reported by Alberto Rosazza, who was born and grew up in Rosazza and experienced directly by himself the decrease of the population and activities organized in the town. Giovanna G. from Vercelli, a local resident who bought a house in Rosazza, refers her personal experience regarding the investment she did with her husband and daughter and also about the services and connectivity in the town. She tells about the opportunity of house on sales. Giovanna G. refers that "the investment was small, because we did not invest a big amount of money, and each time we add some new elements to the house...we are transforming a house that is allowing us to escape from our working dimension and to relax, in a reality that is not so far away from home. My husband is retired and I am not, but I am going and coming back always. It allows us to have more holidays than the general affordable for a family's expenses on other holidays options and destinations. Now with a small amount of money we managed to stay in a very nice, quiet, historical town where there are also teenagers and you can go walking in the nature". On the other hand, Giovanna tells that: "during the summer the situation changes, many people arrive and so several events and celebrations are organized. Something that lacks, on the other hand, is the availability of some services in the town itself". For her, the small market *La strettotia* is enough to satisfy the main needs of the family, but once per week it is necessary to go and reach Adorno's supermarkets and buy a bigger amount of food. Rosazza is a bit isolated in her opinion, although there is the possibility to reach Piedicavallo on the, in order to reach the biggest cities of Adorno and Biella in the south it is necessary to use the car or the public transportation.

Abandoned football pitch. By Salvatore Tartaglia

CONSTRUCTION TECHNIQUES 2.7

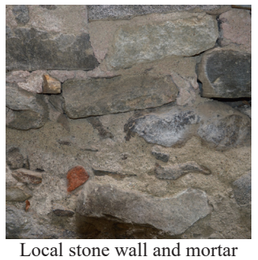
The book *Villages et quartiers à risque d'abandon: Stratégies pour la connaissance, la valorisation et la restauration* [9] in the chapter: "preservation of historic and environmental heritage of Val Cervo "(Piedmont, Italy) provide a detailed framework regarding the construction techniques used in Valle Cervo area and how to interveen in order to preserve the beauty and the value of this mountain area. The northern part of Valle Cervo has experienced a big depopulation in the most recent decades, after a long period of economic and social growth. Beside the case of Valle Cervo, in general the majority of the towns in the alpine regions suffered the disappearance of citizens and relocation in other areas. Although the reduction of number of people in the towns has been experienced in the past, such as in the case of Rosazza, which led to an increase in the number of abandoned houses, offices, shops and public spaces (parks, squares et cetera), the quality of the built environment produced by skilled local workers and craft-men made possible to keep a local historical identity and to have strong and solid houses that survive for decades until today. In fact, the town of Rosazza, in particular, was populated by a big number of local workers in the granite quarries that are present in Valle Cervo and many of them were skilled with the scalpel. Due to the presence of a relevant number of mines the economy of the Valley started to grow and increased rapidly. In fact, the owner of the areas that were characterized by the presence of these materials in the lower parts of the ground, at the beginning started to offer for free the access to the workers and professionist to study the typology of rocks present. Later, when the value of the material was recognized the owner began to promote sales and auctions for acquiring their lands. Considering the big availability and the quality of the stone, it began to be the base of the architecture of the Valley and Rosazza in particular. The stone used is very though and resistant to the weather. Obviously, the presence of cracks in the stone or in the concrete slabs and walls, demonstrate the necessity of an intervention that aims to reinforce the structure at first, before renovating the interiors and the rest of the buildings. The works carried out by the patronage, in the nineteenth century and most of the twentieth century, are characterized by a great construction quality, with consolidated technical knowledge, there are "more prone to firmitas than venustas". The building heritage of the Valley, as already anticipated, although of ancient origin, is characterized by the use of local stone material in large squared ashlars and chestnut (or beech) wood for the horizons and roofs. The vault and arches, that are present mainly in the basement and in the floor above ground are damaged or totally missing. In general the typology of the buildings is simple, with wall boxes up to three-four floors of height or five at maximum. Regarding the interiors of the buildings, it is typical of the pre-alpine and alpine houses. The ground and second floors (or warehouses in the case of more complex structures) contain the main rooms, while one or two upper levels are used for storing wood and hay. These upper levels are typically open on the main facade. Some buildings at high altitude at the mountain grazing are characterized by a very evident simplicity, due to their function of seasonal settlements and are the ones that suffered the biggest damages due to the abandonment and the distance from the town and other villages. In the case of Rosazza, on the other hand, the situation is different because the town was already connected to the other cities of Valle Cervo. In Rosazza, as well as in other towns of the Valley, the centre is characterized by the presence of buildings with walls made of a plaster layers in the outside, which can have a rustic or smoothed finishing. In few cases, represented by the oldest buildings, there is a presence of pictorial decorations that simulates the nobler finishes (ashlar, architectural elements), with a strong use of different colours. Many sacred images are represented with this style. The growth of a capillary crisis of the main sectors (the before mentioned sheep-farming, extraction of syenite and yarn processing) that were maintaining and financing the towns of Valle Cervo, brought to a gradual decline of these realities and led to the abandon of the mountain area especially in the upper and middle part of the valley with a decrease of -90% of inhabitants, from 7000 to 700 people. Many of them had to find other jobs and they went to the biggest city nearby, Biella. In Rosazza, the decline of the population allowed at least to maintain the identity of the site without compromising it with the introduction of different architectural styles that could interfere with the historical heritage. In fact the majority of the historical buildings did not receive any kind of modification. Regarding the residential buildings, particularly those that have been constructed in the late 19th and early 20th centuries, represent a challenge for preserving their original construction materials and techniques. Many of these homes were self-built or constructed using traditional stone masonry, employing hand-quarried granite, terracotta roof tiles, and untreated timber beams. The absence of cementicious mortar in early constructions, replaced instead by lime-based binders, presents difficulties when reinforcing structural integrity. Incompatible modern materials, such as Portland cement, can lead to cracks, moisture entrapment and accelerated deterioration of historical masonry [10].

Some of the most typical construction techniques and materials used in Rosazza can be summurized in: stone masonry, hand-quarried granite, stone roof tiles, timber beams, lime-based binders, rubble stone masonry, squared ashlar blocks, vaulted structures, iron ties and plates.

Abacus of Walls


Local stone wall and mortar


Stone wall and plaster


Local stone wall and mortar


White Plaster


Local granite wall


Retaining street wall

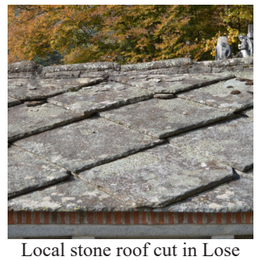

Stone wall and wood


Mustard plaster


Different plasters and mold

Photos by Salvatore Tartaglia

Abacus of Roofs


Local stone roof cut in Lose


Roof with Marseillais tiles


Roof with Marseillais tiles


Roof with Marseillais tiles


Local stone roof cut in Lose


Roof with Marseillais tiles


Local stone roof cut in Lose


Roof with Marseillais tiles


Local stone roof cut in Lose

Photos by Salvatore Tartaglia

Wall Structural Reinforcments

Rosazza is a town classified as risk 4 in the seismic map of Italian cities, which is the lowest value linked to the smallest probability of occurrance and intensity of the earthquakes. On the other hand, it is necessary to consider that, due to the long history of the town, the houses have experienced many stresses due to different change of temperature, high level of humidity and water filtration in the stone walls and rarely seismic waves. All these phenomena have produced some crack in the wall of some buildings and during the survey, some elements were found in those buildings damaged. As shown in the pictures, the metallic supports, which are fixed with bolts and plates, are also called *tie rods* and *chains*. The aim of these elements is to reinforce the stone masonry against fluctuations and shaking which can lead to the collapse of the side walls of the buildings. The chain is a metallic bar that has a strong resistance to traction and the plates are located in the external surface of opposite walls. In so doing the walls are kept together without the risk of fall. The collapse of the structure usually happens in the corners of the buildings, where due to bad connections in the wall, the entire house cannot guarantee the principle of the box structure and the four external walls end up by behaving as four independent elements. Another common ancient technique to limit the risks of collapse, especially in the case of brick walls, is to unstack the bricks in order to dinstribute correctly the loads of the structure in the ground.

Reinforcement plate. By Salvatore Tartaglia

Reinforcement chain and tie rods. By Salvatore Tartaglia

Reinforcement chain and tie rods. By Salvatore Tartaglia

House in Rosazza. By Salvatore Tartaglia

Abacus of Chimneys


Tipolgy 1 of Chimney


Tipolgy 2 of Chimney


Tipolgy 3 of Chimney


Tipolgy 4 of Chimney


Tipolgy 5 of Chimney


Tipolgy 6 of Chimney


Tipolgy 7 of Chimney


Tipolgy 8 of Chimney


Tipolgy 9 of Chimney

Photos by Salvatore Tartaglia

Abacus of Tunnels


Tipolgy 1 of Tunnel


Tipolgy 2 of Tunnel


Tipolgy 3 of Tunnel


Tipolgy 4 of Tunnel


Tipolgy 5 of Tunnel


Tipolgy 6 of Tunnel


Tipolgy 7 of Tunnel


Tipolgy 8 of Tunnel


Tipolgy 9 of Tunnel

Photos by Salvatore Tartaglia

Architecture of Rosazza. By Salvatore Tartaglia

ENERGY CLASSES OF THE BUILDINGS IN ROSAZZA 2.8
PERFORMANCES AND ENERGY OPTIMIZATIONS

In Piedmont and in particular in the mountain towns, the regional monitoring through the SIPEE system and ARPA Piemonte shows that the energy quality of buildings is low [04]. In general, from a national point of view, according to the most recent ENEA-CTI reports on the national building stock, there has been a gradual improvement in energy performance, but still a large share of buildings are in the low-efficiency classes [05].

In the case of Piedmont, for the year 2022 for istance, Arpa Piemonte carried out checks on the correct drafting of Energy Performance Certificates (EPCs) for buildings issued in 2021.

The checks involved analysing a sample of 109,818 EPCs filed with the Building Energy Performance Information System (SIPEE) by a total of 5,957 certifiers. Based on the analysis carried out, which aimed to highlight inconsistencies in the technical data reported in the energy certifications, 2,665 APEs were extracted, corresponding to 2.4% of the total, drawn up by 28 certifiers. The class distribution in Piemonte: for the APEs deposited in 2022, about 67% are in classes E, F, G combined; only about 11% are in the more efficient classes (A1–A4) [06]. Moving the attention to the case study of Rosazza, the analysis of the energy performance of the houses, highlight the strong necessity to intervene in the built environment in order to optimize the retrofitting and the energy consumption. In fact, the majority of the buildings presents the lowest in the Italian Energy Performance Certificate (EPC) system, that is the Energy Class G. Which means that the buildings presents a very bad thermal insulation, inefficient heating systems with high consumption and so small efficiency, bad stratigraphy layering, cracks and thermal bridges in the external envelope of the houses and lack of renewable energy systems.

The majority of the 60% buildings analysed that felt under the condition of class G, with the most significant necessity to introduce energy retrofitting strategies, a big part of them reached a total amount of more than 175 kWh/m²y. Among them there is a peak value represented by the consumption of a building of 654 kWh/m²y that exceed considerably the national benchmark. Although the presence of a substantial number of building with very high energy consumption and so also the environmental impact, there is a small portion of the houses assessed that presents better values of consumption. Those buildings are mainly the ones that have been recently renovated due to their use and importance in the city, it is the case of the town hall or the parish church for instance, that even if present a big floor are, the energy consumption is controlled.

In order to obtain precise data of the energy performance of the buildings, the data set of GIS data was consulted and thanks to the use of QGIS (Quantum GIS), OSM (Open street map) were used in order to obtain a comprehensive visualization of the performances. Finally the integration with BIM allowed to performe also a predictive analysis, with thermal simulations for instance, about the potential improvements that could be obtained with certain design choices. This data driven methodology helped to understand the specific problems of the houses and to simulate what choices to take into account in order to reach the lowest energetic demand. Eventually, the integration of technical systems in the design phase, such as photovoltaic panels, linked to a further simulation would have provided an additional understanding of the energy supply beyond the already known energy demand.

The following table represents a part of the total number of buildings in the town, with informations related to their location, the area [m^2], the number of floors, the energy class and the annual energy consumption [kWh/m^2year], the data were collected by Afsaneh Akbari [10]. The combination of the calculations related to the consumption with the geometrical output created through BIM models allows to have a clear and precise understanding about the energy performances of Rosazza. This effort can also help the municipality to set a plan of energy retrofitting starting from the buildings highlighted in red, with class G energy consumption. In general, it is also to consider that, for some buildings of Rosazza, it was not possible to obtain the exact annual energy consumption and in those cases the energy classification has not been performed for inconsistency of the data collected.

B. Function	Location	Area [m2]	N. of floors	Floors	Energy class	En. Consumpt./year
R.	via Amba Alagi, 12	180.0	6	all	G	_
R.	via Umberto I, 10	75.0	4	4	G	175,1 kWh/m2year
R.	via Costantino Crosa, 2	130.0	6	all	E	_
R.	via Roma, 39	228.0	4	all	G	294,85 kWh/m2year
R.	via Sp100, 57	148.0	4	all	_	_
R.	via E. Mosca Riatel, 7	130.0	3	all	_	_
R.	via Federico Rosazza, 17	100.0	4	all	G	435 kWh/m2year
R.	via Quintino Sella, 5	60.0	3	all	G	_
R.	via Umberto I, 10	150.0	4	1	G	_
R.	strada provinciale 100 Nn	40.0	n.a.	2	G	_
R.	via Federico Rosazza, 11	90.0	1	1	G	315,52 kWh/m2year
R.	via Federico Rosazza	50.0	4	3	G	_
R.	via Roma, 59	148.0	4	all	G	_
R.	via Re Umberto I 10	n.a.	4	1,2,3	G	_
R.	Valmosca 123, Campiglia Cervo	275.0	4	all	G	425,00 kWh/m2year
R.	vendita a Rosazza	170.0	3	all	G	_
R.	Valmosca 112	60.0	3	all	G	654 kWh/m2year
R.	Valmosca 97	120.0	3	all	G	> 175 kWh/m2year
R.	Via Roma, 42	70.0	3	3	F	_
R.	Via Roma, 60	85.0	3	3	F	_
R.	Via Almba Alagi, 2-5	90.0	2	_	_	_
R.	Via Milano, 10	1000.0	2	_	D	100 kWh/m2year
Town Hall	Via Roma, 1	2000.0	n.a.	_	C	50 kWh/m2year
Parish church	Piazza Mazzini, 2	500.0	n.a.	_	C	50 kWh/m2year

Table 1: Energy performace of a sample of buildings in Rosazza. Data collected by Afsaneh Akbari

2.9 CONSERVATIVE RESTORATION OF ROSAZZA: LEGAL AND URBANISTIC FRAMEWORK AND TIPOLOGY OF INTERVENTIONS ALLOWED

The project of restoration of the houses in Rosazza, needs to take into account some specific restrictions and consideration due to the value of the heritage of the town and its history. Specifically, the two most important urbanistic tools to be considered for the interventions in the area of Rosazza and its built environment are: the Piano Regolatore Generale (PRG) of the town of Rosazza and the Norme Tecniche di Attuazione (NTA) [11] [12]. The first one is the main urban planning instrument used by Italian municipalities and to be considered for long term transformations of the cities. It also divides the municipality into different area specifying how land can be used based on their function into: residential, industrial, agricultural, public services, etc., where development is allowed, and what areas are protected or reserved for public use. This instrument controls also the building density, volume limits, infrastructure networks (roads, green areas, public transport, utilities) and takes into account also the preservation of environmental, historical and cultural assets.
On the other hand, the Norme Tecniche di Attuazione (NTA) are the technical and regulatory guidelines or directives that come with the PRG. They offer the specific legal structure for explaining how the Piano Regolatore Generale should be used. Specifically, the NTA controls some aspects such as:
-Building regulations and standards (heights, setbacks, coverage, etc.),
- Procedures for permits and compliance
-Specific constraints or requirements for each zoning area
-Implementation rules for urban development projects and infrastructure.
The PRG of Rosazza (Piedmont) for the interventions in the buildings define:
1) Ordinary Maintenance
2) Extraordinary Maintenance
3) Restoration and Conservative Rehabilitation
4) Building Renovation
Each one of them is defined as follow:
1) Ordinary Maintenance:
"Le opere di riparazione, rinnovamento e sostituzione delle finiture degli edifici e quelle necessarie ad integrare o mantenere in efficienza gli impianti tecnici esistenti, purché non comportino la realizzazione di nuovi locali né modifiche alle strutture od all'organismo edilizio" (L.R. n°56/77, art. 13)" which is translated as: Repair, renovation and replacement works on building finishes and those necessary to integrate or maintain the efficiency of existing technical systems, provided that they do not involve the construction of new premises or modifications to the structures or building complex.
More specifically, it represents all the interventions such as small works of

replacing floor tiles, doors, or windows without changing shape or materials, fixing the gutter etc. In general there is no need of permission from the municipality in order to perform these works.

2) Extraordinary Maintenance:

“Le opere e le modifiche necessarie per rinnovare e sostituire parti anche strutturali degli edifici, nonché per
realizzare o integrare i servizi igienico-sanitari e gli impianti tecnici, sempre che non alterino i volumi e le
superfici delle singole unità immobiliari e non comportino modifiche delle destinazioni d’uso” (L.R. n°56/77,
art. 13).” which is translated as the works and modifications necessary to renovate and replace parts of buildings, including structural parts, as well as to
create or integrate sanitary facilities and technical systems, provided that they do not alter the volumes and
surfaces of the individual property units and do not involve changes in their intended use (Regional Law No. 56/77,
Art. 13).

They represents the works that improve or partially modify the building but without changing its structure or intended use, such as changing internal layout (e.g., modifying walls),
replacing roof beams, windows, or floors with new materials.

Installing or updating systems (heating, plumbing, insulation) are also considered as extraordinary interventions. In this case, on the other hand, there is the requirement of getting the CILA (Comunicazione di Inizio lavori asseverata) or sometimes SCIA (Segnalazione Certificata di Inizio Attività). While the CILA is a formale communication required for invasive extraordinary maintenance that does not involve structural changes, such as: moving internal, non-load-bearing partitions, changing internal doors, renovating electrical or plumbing systems; the SCIA, on the other hand, is a certification and notification for more significant activities or changes in the intended use of a property, such as: dismantling, refurbishing roofs or lofts, significant structural fixes, or altering the function of a building. Moreover, the works can start right after the SCIA is filled.

3) Restoration and Conservative Rehabilitation:

“Gli interventi rivolti a conservare l’organismo edilizio e ad assicurare la funzionalità mediante un insieme
sistematico di opere che, nel rispetto degli elementi tipologici, formali e strutturali dell’organismo stesso, ne consentano destinazioni d’uso con essi compatibili. Tali interventi comprendono il consolidamento, il ripristino ed il
rinnovo degli elementi degli elementi costitutivi dell’edificio, l’inserimento degli elementi accessori e degli impianti
richiesti dalle esigenze dell’uso, l’eliminazione degli elementi estranei all’organismo edilizio” (L.R. n°56/77, art. 13)”. which can be translated as: interventions aimed at preserving the building structure and ensuring its functionality through a systematic set of works which, in compliance with the typological, formal and structural elements of the structure itself, allow for uses that are compatible with them. These interventions include the consolidation, restoration and renovation of the building’s constituent elements, the addition of accessories and systems required by the needs of the building, and the installation of new services. Such interventions include the consolidation, restoration and
renovation of the building’s constituent elements, the addition of accessories and systems required for its use, and the removal of elements that are foreign to the building structure’ (Regional Law No. 56/77, Art. 13).

In other words they are the works focused on maintaining the historical, architectural, or cultural significance of a structure while permitting functional modifications and adaptations. Some of these works are: the structural consolidation of walls, arches, roofs.The restoration of original architectural elements. The limited changes to improve usability (bathrooms, utilities) without altering volumes.

In terms of legal permissions, in this case it is usually required to have a SCIA or permit to build, and if the building is vincolato (protected by heritage laws, which is likely in Rosazza), you also need authorization from the Soprintendenza.

4) Building Renovation:

“Gli interventi rivolti a trasformare gli organismi edilizi mediante un insieme sistematico di opere che possono portare ad un organismo edilizio in tutto o in parte diverso dal precedente. Tali interventi
comprendono il ripristino o la sostituzione di alcuni elementi costitutivi dell’edificio, la eliminazione, le
modifica e l’inserimento di nuovi elementi ed impianti” (L.R. 56/77 art. 13).

In other words they are the interventions aimed at transforming buildings through a systematic set of works that can result in a building that is wholly or partly different from the previous one. Such interventions include the restoration or replacement of certain constituent elements of the building, the removal, modification and insertion of new elements and systems. So they are the works that alter structure or appearance significantly, possibly changing use or volume, such as adding new windows or openings, changing the building’s intended use. In this case it is necessary to present the SCIA or the permit to build, depending on the specific work to be performed.

For the purposes of this master’s degree thesis, the project aims to renovate one specific existing building that acts as a pivot project for further other projects that can follow the same methodology and obtain good result with time efficency and high accuracy.

In a more detailed way, the scenario presented in the thesis is the one of a potential investor, represented by a privat entrepeneur or a the public administration (such as the municipality) who want to invest in restoring a building for creating a plus value in the future, by creating a new house ready to be sold or rented in real estate market. In so doing, the building can represent the starting point for other investments that can attract tourists.

The hypotetical intervention that has been analyzed is specifically described in the point (3): restoration and Conservative Rehabilitation, to provide a functional re-adaptation of the house.

MOUNTAIN TOWN STATUS AND ITS IMPACT: ON INVESTMENT AND RESTORATION STRATEGIES

2.10

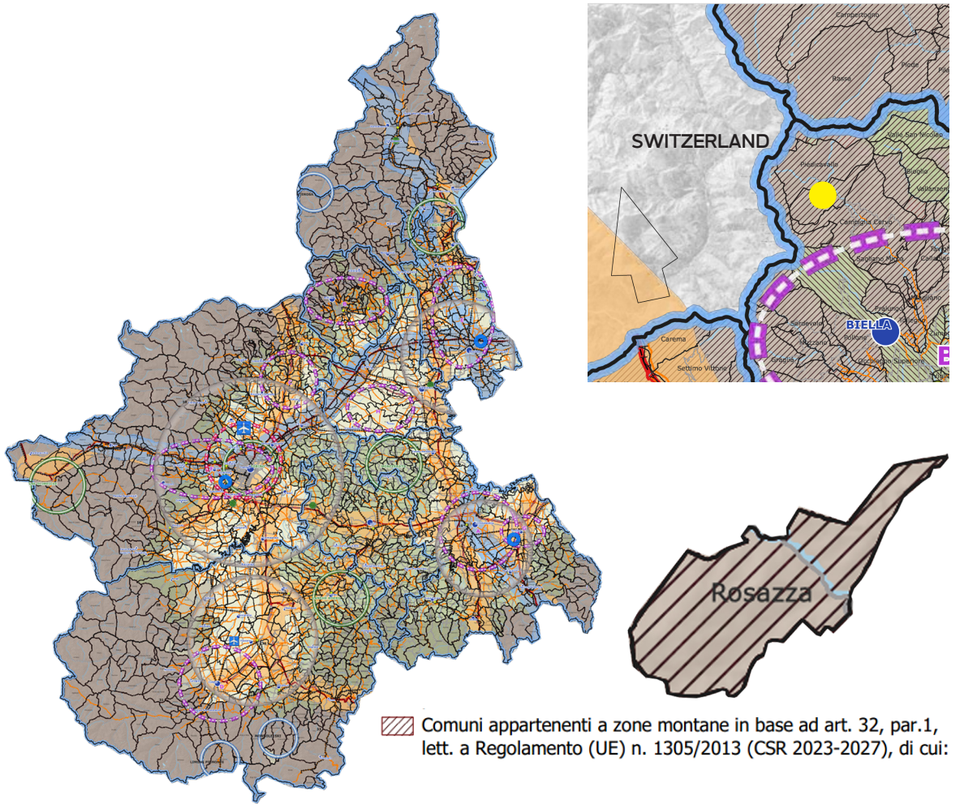


Figure 11: PTR (Piano Territoriale Regionale) Regional Territorial Plan of Piedmont

The municipality of Rosazza, located in the Province of Biella, Piedmont, is officially classified as part of a mountain area pursuant to Article 32, paragraph 1, letter A) of Regulation (EU) No. 1305/2013, as implemented in the Italian Strategic Plan for the Common Agricultural Policy (CAP) 2023–2027 [07]. This designation implies the presence of significant natural constraints, such as elevation and terrain steepness, which qualify the area for specific European and national rural development measures.

In terms of tourism, this classification enables Rosazza to benefit from targeted funding and policy initiatives aimed at promoting sustainable tourism, including the development of eco-tourism, cultural tourism, and the restoration of historical infrastructure for tourism-related purposes. As a historically and architecturally distinctive mountain village, Rosazza holds considerable potential for the tourism, particularly those interested in heritage, esothericism, and alpine landscapes.

Regarding the restoration of the built environment, the mountain area status provides access to public funding schemes dedicated to the conservation, rehabilitation, and adaptive reuse of historical buildings. This includes financial incentives for energy-efficient renovations and the recovery of traditional architecture for residential, cultural, or entrepreneurial functions. The availability of such support frameworks makes Rosazza an interesting case study for interventions that combine heritage conservation with local development.

From the perspective of real estate and investment, Rosazza's location within a recognized mountain zone implies lower entry costs, favourable fiscal measures, and the possibility of getting public funding to enhance property value through renovation projects. The broader policy framework supports investments in hospitality structures, rural enterprises, and digital and energy infrastructure, improving the economic attractiveness of the area for both private investors and public-private partnerships.

Moreover, Rosazza is eligible for various funding instruments under the CAP, the Rural Development Program (RDP) [08], and Italy's National Recovery and Resilience Plan (NRRP) [09]. These include compensatory for agricultural activities in disadvantaged areas, start-up support for young farmers, incentives for short supply chains and rural tourism, and grants for renewable energy and digitalization in marginal areas.

Overall, the formal recognition of Rosazza as a mountain municipality under EU and national frameworks establishes a favorable legal and financial context for sustainable investment, restoration, and rural regeneration initiatives, which together underscore the village's unused potential for integrated territorial development.

Another important investment plan offered by the European Union is the Next Generation EU (NGEU) [010] National Plan for Villages that represents a big source of finances for attracting tourists in the abandoned but valuable towns. In fact, as described by the italian Ministry of Culture, "Many small Italian historic centres (Borghi) offer enormous potential for alternative sustainable tourism, thanks to their cultural heritage, history, arts and traditions... meausures will be implemented aimed at restoring historical heritage, redeveloping open public spaces (e.g. removing architectural barriers, improving street furniture) and creating small cultural services, including for tourism purposes. Secondly, the creation and promotion of new itineraries (e.g. themed itineraries, historical routes) and guided tours will be encouraged. Finally, financial support will be introduced for cultural, creative, tourist, commercial, agri-food and craft activities, aimed at reviving local economies by promoting local products, knowledge and techniques." [011]. These are only some of the potential founds that can encourage private and public investors to finance projects in Rosazza. A further big source of founds can be obtained from energetic optimization of the buildings and introduction and technologies in Rosazza.

Tower of the Castle of Rosazza. By Salvatore Tartaglia

Civic Tower of Rosazza. By Salvatore Tartaglia

METHODOLOGY

3

Digitalization of the mountain town

The integration of GIS and BIM in a workflow that merges together geographical informations with a three-dimensional, data-rich environment of building information modelling can effectively provide a multi-scale understanding of the morphology, infrastructures, land use, environmental constraints and risk conditions, which are essential to frame the village within its broader territorial case. In the context of fragile towns or cities that face relevant environmental challenges, the use of this integrated methodology represents an essential key for achieving sustainable goal with the aim of forecasting and promoting more resilient environments. [012] In these terms, merging together these technologies can establish a system that can be progressively enhanced with real-time or near real-time information.
Thanks to the use of a sensor networks, Internet of Things (IoT), the model can evolve from a static digital representation to a dynamic Digital Twin. The development of the model can provide the opportunity to simulate different scenarios, to predict necessary maintenances and to help the management of the project during all its life cycle. All these considerations can help the facility management sector and provide the data essential in the process of development of Smart Cities.

DIGITAL TWIN AND ONTOLOGY

3.1

The concept of a Digital Twin (DT) traces its origins in a book titled *Mirrored Worlds* published around thirty years ago.
After that, a gigantic number of definition and descriptions have been produced to define such a clear concept with high complexity behind of it. In fact, simply by searching Digital Twin on *ScienceDirect*, a major database of peer-reviewed scholarly literature appears with more than 52,495 results that can be identified. The article by K. Hribernik et al. (2013) [12], provides among the others, a clear definition of Digital Twin as follow: "Digital Twin is defined as a software representation of a physical asset, system or process designed to detect, prevent, predict and optimize through real time analytics to deliver business value". This concept has developed more and more throughout the history, hugging different branches of science, such as smart manufacturing as first, followed by industrial engineering and later by aerospace and built environment. Although it is less developed compared to other fields, digital twin for the built environment represents a very important field, where several improvements can be obtained by creating smart cities.
The creation of a digital twin, on the other hand, requires very sophisticated technology and considerable efforts.
In fact, in order to produce a model of a city or of an asset that acts like a digital twin it is necessary to collect a big amount of data of the object analysed, to represent it with a significant precision and to implement technological devices that can communicate continuously data in between the expert and the object. In fact, the peculiarity of the model is its "dynamism" and the bidirectional transmission of data, which means that it is able to continuously provide information to the database and receive data from it. It can be consider as a living asset, not an already made and static model.
The creation of the digital twin of a building or a city, requires the 3D model of them and the introduction and use of sensors that can communicate informations related to change in the gradient of the temperature, seismic waves, increase or decrease of the wind speed, amount of snow collected in a specific surface and so on. As defined by Ivanov, S. et al. (2020) [13], "the DT approach relies on the ability to receive and effectively process data flows collected automatically through distributed "internet of Things" (IoT) sensor systems. The DT of the city is gradually filled with the data of the real city, collected in real-time from deployed IoT infrastructure and urban information systems. DT supports forecasting of changes in the state of urban infrastructure, and to offer optimal solutions by analysing information on the dynamics of people and transport, their interdependence and their fluctuations in time and space. In addition, regardless of the current state, the digital twin allows analysts to answer "what if" questions, helping to understand how cities equipped with intelligent technology, will function in a particular economic, environmental and social conditions, and identify the factors that contribute to possible failures"[14]. Thanks to the data collected it is possible , among the other things, to prevent future catastrophes and to create more resilient cities that can be controlled before the outbreak of floods, earthquakes and other natural disasters. Moreover, it is feasible to assess predictive maintenances and improve some crucial aspects of the social and environmental spheres, such as: traffic, utilities, energy consumption et cetera.
Considering this, the potential of digital twin can be even more exploited if the digitalization, modelling and data collection is carried out in fragile contexts, due to social, environmental and economical aspects. It is the case of the abandoned towns or the cities that are frequently exposed to natural catastrophes. All these aspects can bring uncertainity and compromise the achievement of a sustainable development. In these terms, the article by C. Chioni et al. (2023) [15] highlights the importance of the adoption of a TDT (territorial digital twin) for the management and improvement of the conditions of the fragile mountain inner areas, with an increase in the capacity of these areas to face environmental complex challenges with a sustainable approach and to resolve different types of hazards. Specifically two cases are presented in the article: the first case study is represented by the Val di Sole in Trentino-Alto Adige, that is an alpine valley that faces several antropocentric and natural risks due to the presence of strong tourism hydrogeological risks and the epicentre are of the 2016-2017 earthquake in the Central Apennines, that have experienced a natural disaster. The TDT was obtained with the use of photogrammetry, GIS mapping and space syntax analysis based on the case and the necessity. The territorial digital twin of the two case studies, was produced with the aim of satisfying and respects the principles of the *Sendai Framework for Disaster Risk Reduction 2015-2030* (*SFDRR*), which outlines seven clear targets and four priorities for action to prevent new and reduce existing disaster risks, such as the identification of the main risks, the empowering of the strategies to reduce them, the investment in town's resiliency plans and the preparation of an immediate and long term response to the events. In addition to the before mentioned directives established by the UN World Conference on Disaster Risk Reduction in Sendai (Japain) in 2015, the Italian government adopted the Strategic Planning Instrument (SNAI) to identify the marginal towns of the country, as shown in the map at pages 31-32. Considering this, in order to preserve the fragile town of Rosazza, a further challenge of this master's degree thesis, will be to develop a territorial digital twin of the town, that can help to prevent and mitigate the floods in Rosazza (as presented at page 26) and that can provide, among many other things, a further optimization of the real estate.

DIGITALIZATION OF ROSAZZA: 3.2
3D MODEL OF THE TOWN

The town of Rosazza, object of the case study of this master's thesis, has been modelled in order to produce a 3D model of the site, by detailing the topography and the constructed environment. The model produced by Afsaneh Akbari, has been integrated with more detailed data regarding the total height of all the buildings, the detailing and the development of more precise model a smaller scale object of the renovation. Finally, the BIM model of the building, the cost estimation of the interventions of restoration, the economical and financial real estate analysis were performed in order to understand the possible scenarios for future private and public investors, who want to finance the project and contribute to the effort of revitalizing the mountain semi-abandoned town.

The work-flow followed in order to obtain the topographical model was to create a first geographical information system representation of the town, thanks to the GIS data and the software QGIS and Openstreetmap. The first one is a software used to edit, produce, observe, assess and disseminate geo-spatial data with high accuracy and possibility of editing colours, layer and adding informations. Furthermore, it enables you to handle various kinds of data, including vector and raster data and to produce tailored maps. Openstreetmap is a joint initiative that develops a worldwide map of open geographical data, a sort of library of interactive maps. Anyone can participate in gathering and refreshing this information, which is accessible at no cost for any purpose, including the development of maps, applications, and various services. The GIS data must encompass comprehensive topographical details, that distinctly outlines the height , inclination and terrain characteristics which influence constructing efficiency and sustainability plans. Following the order of the work-flow, the data collected from Google earth, Google maps, and especially from Openstreetmap were collected and then elaborated through OSM and QGIS, that helped to create a complete reliable dataset that mixes informations regarding context, heritage, natural elements and topographical data.

The importance of QGIS is evident considering also the possibility of using several plug-ins that allow to performe specific and accurate analysis and representations in the model. The installation of QGIS, as well as downloading the plug-in from the tool bar of the software, is completely free of costs, which makes this software the one of the best datasets compared to other applications which need a paid subscription. Some of the most know plug-ins that have been used also for the purpose of this

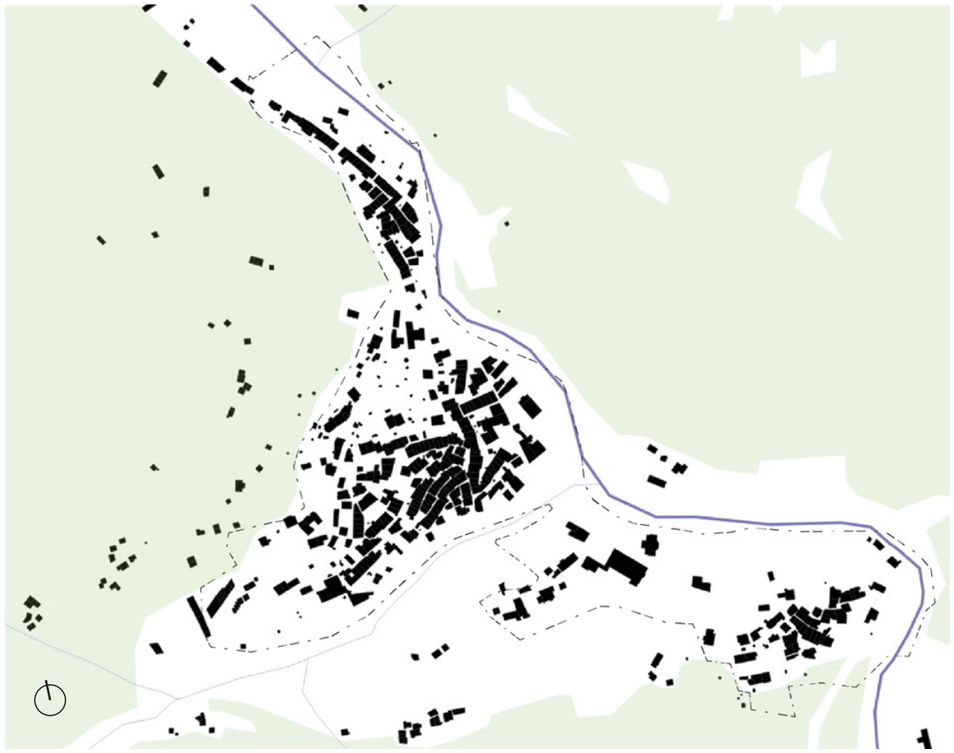


Figure 12: table of the total number of buildings, typology and their height, made with QGis and OSM. By Salvatore Tartaglia.

master's degree thesis are: QuickOSM Following this, thanks to the integration of GIS data and BIM modeling, a further relevant improvement can be achieved. This approach of merging together data coming from both is a recognized and valid instrument for detailed data acquisition and heritage conservation, as demonstrated by Tsilimantou, E. et al [16] and Afsaneh Akbari. The building information modeling methodology in fact, allows the professionist to simulate and performe a massive amount of study in the architectural and engineering fields. After the development of a BIM model, for istance, it is possible to produce energetic, economics, solar, thermal, simulations and many other analysis. As before mentioned, once the geographical infromations were collected, some maps of Rosazza were produced with the aim of highlight the urban context and the ratio between full and voids, that provides a clear and immediate understanding of the urban pattern. The map on top represents an edited version of the famous Nolli map, by the Italian geometer and architect Giambattista Nolli (1701-1756).

This version produced through Open Street Maps, QGIS shows clearly the buildings of the town, the mountains and the river.

It also highlight the other buildings spread far from the town centre.

Furthermore, as can be seen in the map, the presence of very narrow streets and so a very dense built environment creates a big challenge for the design of restorative projects in the houses. Especially in the centre of Rosazza, the buildings are extremely close each other and the streets are particularly narrow. The reasons behind the design of the historical urban fabric was to try to imprison the heat produced by each house and limit as much as possible the dissipation of it.

Moreover, the majority of the houses share their external walls with the houses next to them, not only for saving materials and reduce the costs, but also for heating purposes. The use of geographical datasets helped not only to obtain a top view of Rosazza, but in particular helped in the process of vectorization of the mountain town, that was done thanks to the use of GIS, with data coming also from OSM and DEM, that stands for digital elevation models and helped to produce the final 3D representation of the context.

Following the geographical representation of the urban context and natural environment, the model has been exported from QGIS and imported into the CAD software Rhinoceros, also known as Rhino, which represents one of the most used and flexible software to manage geometries. In fact, the software works with NURBS (non uniform rational B-splines), that are a mathematical model which allow the generation and the management of data for representing curves, free form surfaces in a very accurate way. Moreover, Rhino is one of the most versatile software in the market, due to the high interoperability optimization, and so to the possibility of exporting and importing models in different formats without loosing precision.

The most used format in order to export and import data among software is the IFC (Industry Foundation Classes) that allow multiple operators to access, edit and send models and drawings using the same or different software. The purpose of this format is to enable the exchange of an information model without loosing or modifying the data embedded into it. The IFC architecture is structured on semantic, properties and relations that guarantee the presence of geometries, costs, location, energy data et cetera. In other words, in order to define an IFC model it is necessary to precise that they are:

- geometric and non-geometric entities;
- the models contain not only the geometry of the building but also the data associated with the elements;
- exporting the data of a project carried out using the BIM methodology by means of an IFC file transfers the data from one application to another;
- the IFC format is easy to read and open, although it collects a lot of data inside of it (G. Piras et al. 2024) [17].

The translation to IFC, which can be accomplished by converting QGIS vector layers into IFC entities utilizing plug-ins or intermediary tools. This translation is made possible by a number of work-flows and open-source tools, including QGIS2IFC, IFC export, and bespoke Python scripts built on top of IFC Open Shell. By preserving both geometric and semantic integrity, this procedure makes

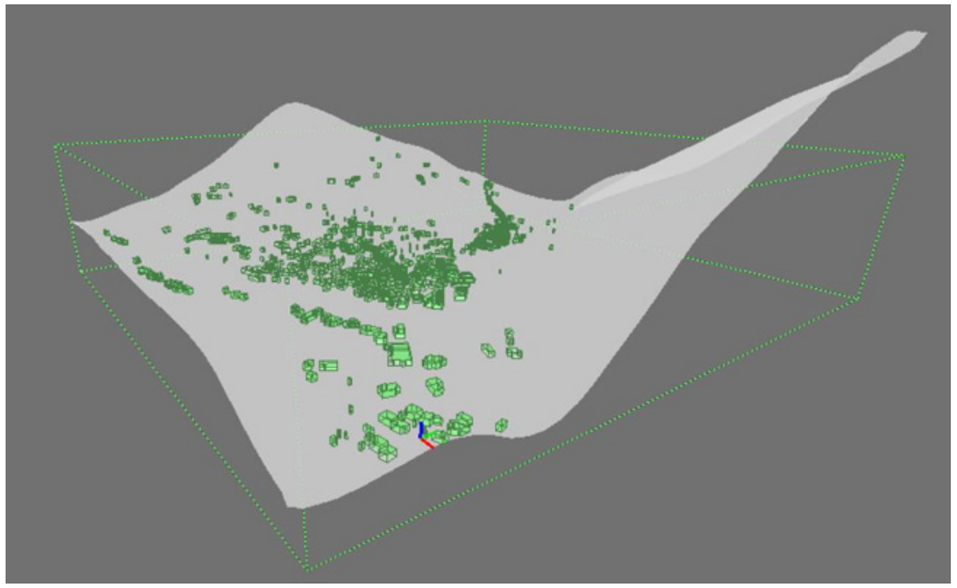


Figure 13: GIS based vectorization and 3D model of topography and buildings, made with Rhinoceros.
Credits: Afsaneh Akbari

sure that non-geometric data like material kind, height, or classification is kept inside the IFC format.

After the IFC model is generated and exported, It can be directly imported in Revit.

In this stage, the coordinates, geometry, and property data that are embedded in the IFC are elaborated by the BIM environment. A well-structured IFC allows the import procedure to retain the majority of the original QGIS data, producing a

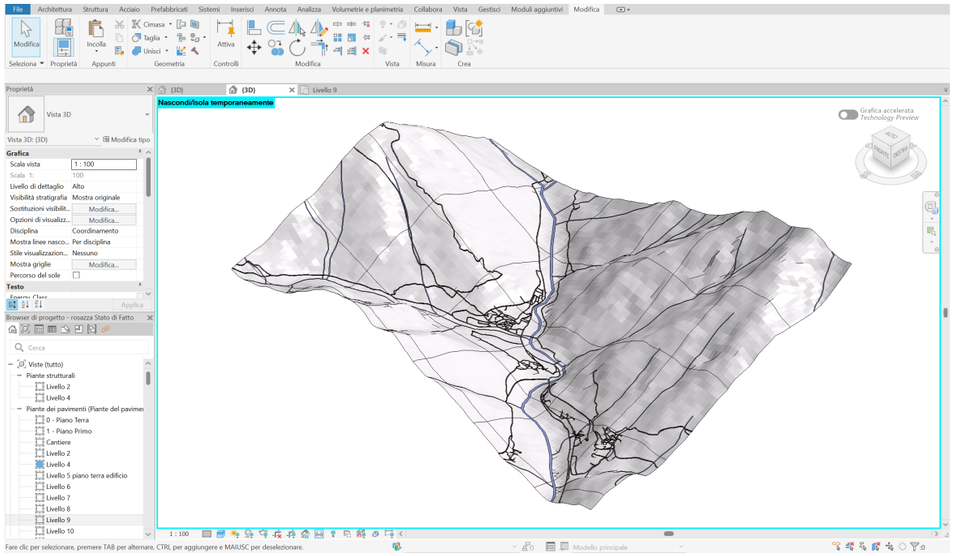


Figure 14: 3DM model of the Topography imported in Revit. By Salvatore Tartaglia.

Figure 15: 3D Model of Rosazza and the buildings. By Salvatore Tartaglia

geo-referenced BIM model that retains the geographic accuracy of its GIS counterpart in the real world. A correct work-flow allows the expert to generate interoperable models that can be used in a urban-scale, for analysis and decision making, environmental simulation, based on energetic studies, infrastructure planning and digital twin developments. Even if the potential of this procedure is evident, there are some studies that highlight the necessity of improvements regarding the precision of the data and the small challenges to face during the process of exchange of projects among software. In fact, in the articles by Sani & Abdul Rahman, et al. 2018 [18] and Slongo et al. 2022 [19], it is demonstrate the possibility to loose data in the process. Once the IFC model is imported in Revit, there are several possibilities of use of the model that can be done. Starting from the use of the project as a contextual base for other goals and decisions, to the site planning and environmental analysis, with regards to the correct orientation of the buildings and the proper accuracy of the topography. Inside the BIM environment the data collected from energetic, economical, financial, urban studies can be integrated. Many experts can contribute in the process of editing and updating the model, through the possibility of working with links or with a central model. In the first case, through the BIM methodology it is possible to generate singular models, e.g. a model of the structure of the buildings, and to load or unload the secondary models into the main one. This allows to obtain light models that, on the other hand, need to be updated constantly and refreshed inside the main one. Working

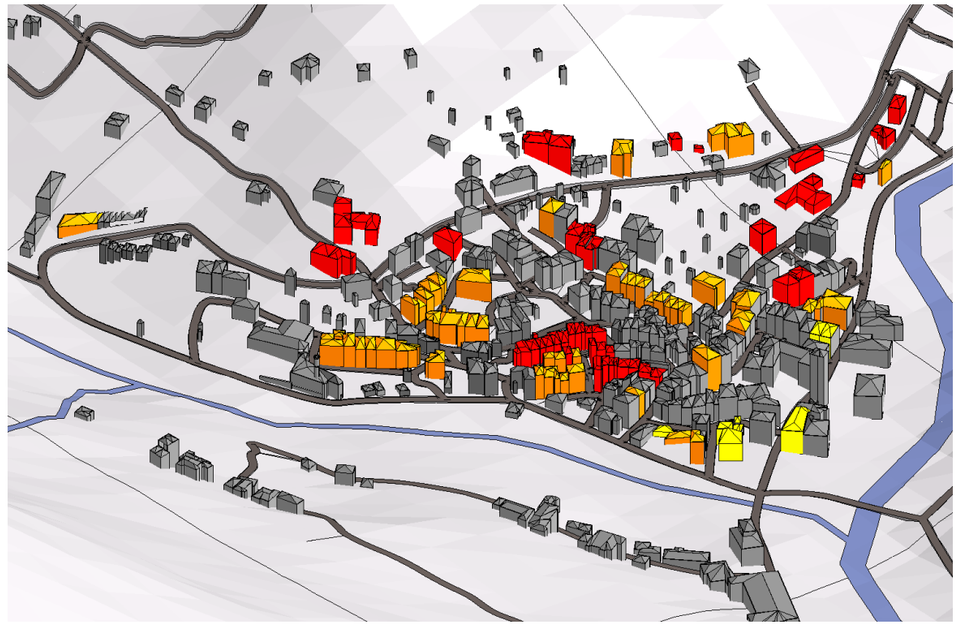


Figure 16: BIM model with the energy classification mapping according to the table [1]. By Salvatore Tartaglia

with a central model, instead, require the access for the expert that can directly edit an integrated project after the owner of the model gives the permission to do it. This last procedure is more compelx compared to the first one.

- *The Energy Performance model*, shown in figure 12, provides an overview of the buildings previously analyzed in terms of energetic performances in the table 1, that are now represented in the BIM model of Rosazza. The colours of the buildings are red, orange and yellow and represents the different energy class. Although the accuracy of the energetic classification is not very high, It can be seen in the project that the majority of the houses are red, which means that they are in class G. Especially in the area of the town with the highest density of houses.

The orange buildings represent the energetic class F and, as well as the red one, the majority of them is located in the centre. Probably, due to the before mentioned difficulty to access the houses in the centre of the town due to the narrow streets, it may be that many energetic improvements and retrofittings have not been made, for the higher prices and complexity of the interventions.

Finally, there are only few building in class E (the yellow ones). Some data related to the energy consumption and classification in the APE (the document that assess the energetic performance of the buildings). The result of the assessment must be available to the clients in the cases of buildings that are on the real estate market, for renting, sale and auctions opportunities. Moreover, in case of renovations and energy retrofitting the report needs to be available.

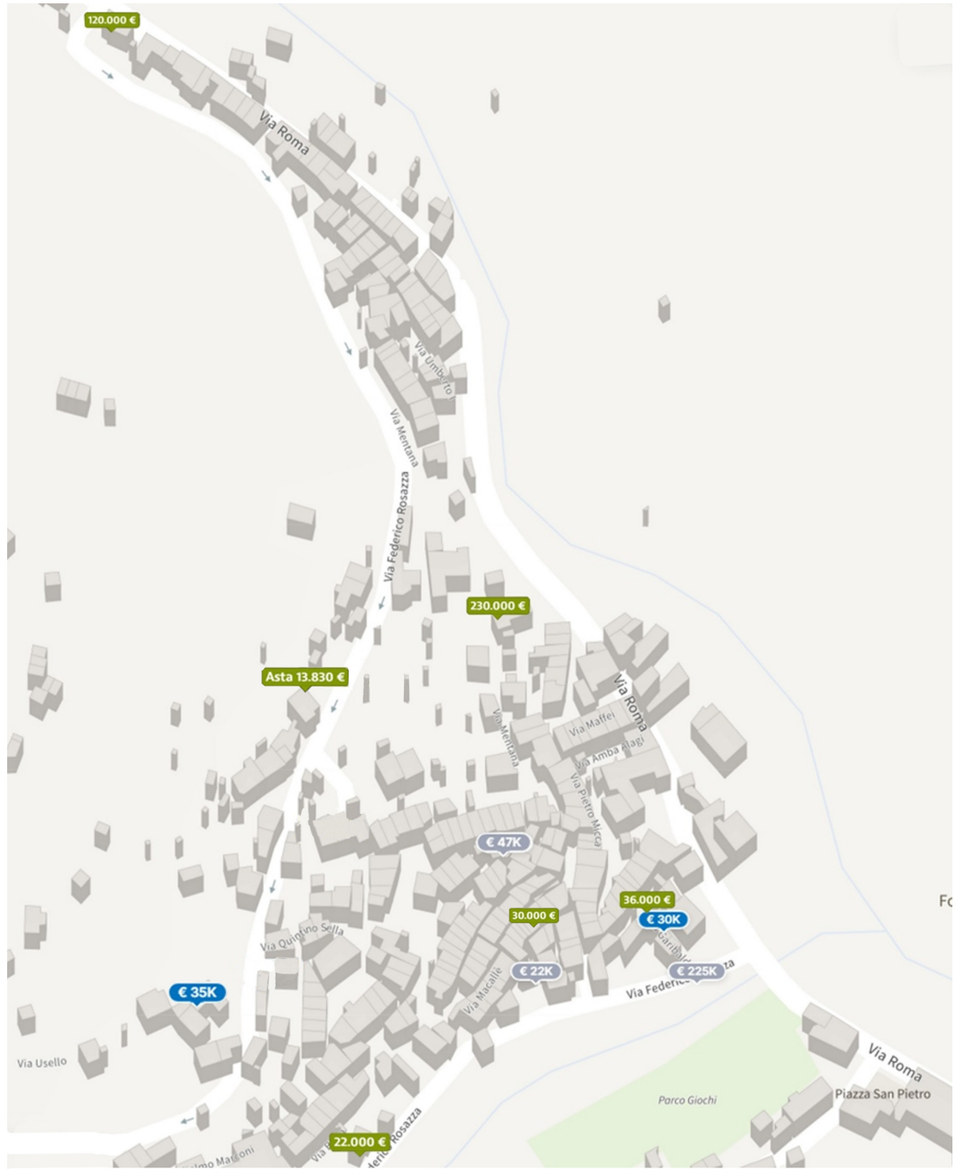


Figure 17: General view of the real estate announcements in the market. By Salvatore Tartaglia

Regarding the real estate market, this general view of Rosazza merges together all the data collected from the real estate websites: Idealista.it [013], Immobiliare.it [014], Trovacasa.it [015], Subito.it [016], Nestoria.it [017] with the data collected in September 2025. The value of the houses is obviously based on the size of the properties, conditions of them and other services that they can offer. The majority of these houses on the market require several interventions in order to

repair cracks in the walls, installing new technological devices and sometimes also intervening in the insulations of the walls and the ground floor in order to fix the problem of the rising humidity. The values of the offers are:

1) 35'000 €
2) 47'000 €
3) 22'000 €
4) 30'000 €
5) 225'000 €
   230'000 €
6) 36'000 €
7) 120'000 €
8) 30'000 €
9) Auction starting from 13'830 €

The last option is an auction, so it is not possible to understand if the property will be sold or not until the day of the trade. Eventually, in case of property sold, we cannot know now the final value of the selling. Among the other properties in the market, the are few ones that are quite expensive compared to the others that have an average value of 31'714 €.The ratio between the total cost of the house and its floor area provide the price per m^2 of the property, which is necessary in order to have a first understanding of the investment. After rationalizing the prices the results are the followings:

1) 35'000 € / 290 m^2 = 121 €/m^2
2) 47'000 € / 170 m^2 = 276 €/m^2
3) 22'000 € / 139 m^2 = 158 €/m^2
4) 30'000 € / 80 m^2 = 375 €/m^2
5) 225'000 € / 381 m^2 = 590 €/m^2
   230'000 €/ 330 m^2 = 697 €/m^2
6) 36'000 € / 207 m^2 = 174 €/m^2
7) 120'000 € / 269 m^2 = 446 €/m^2
8) 30'000 / 60 m^2 = 500 €/m^2

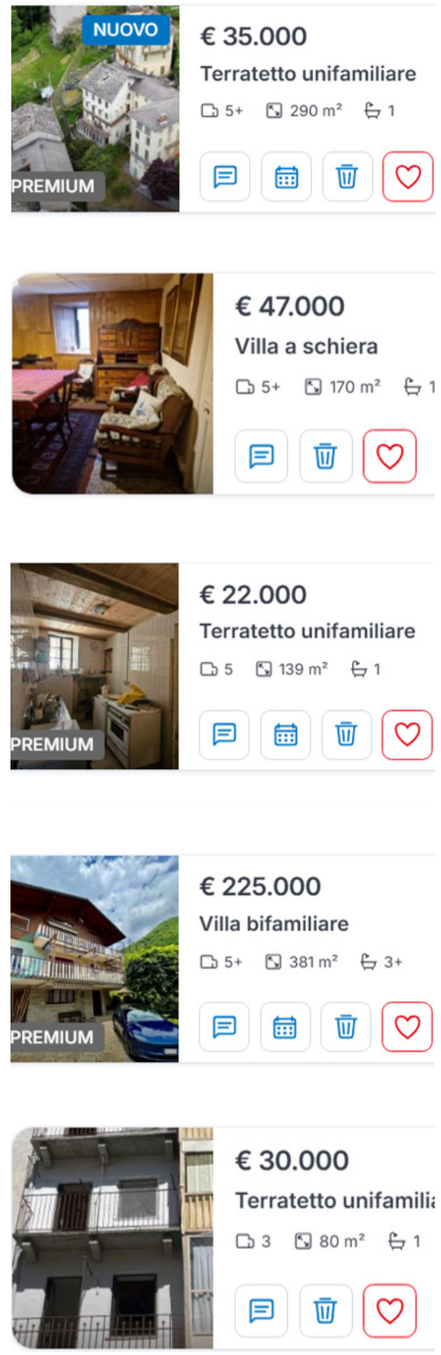


Figure 18: Real estate opportunities in Rosazza. Source *Idealista*

Villetta bifamiliare in Via Federico Rosazza, 1, Rosazza

230.000 €

Box compreso

9 locali 330 m2Villa a Rosazza (BI)

Senza foto

Richiedi foto all'inserzionista

Villa in SP100, 73, Rosazza

120.000 €

8 locali 269 m2

Casa indipendente in Via Umberto I, 8, Rosazza

36.000 €

7 locali 207 m2

Bilocale in Via Federico Rosazza, 25, Rosazza

Da **13.830 €**

2 locali 138 m2 Piano terra senza

Villetta a schiera in Via Quintino Sella, 5, Rosazza

30.000 €

2 locali 60 m2

Casa indipendente in Via Garibaldi, 6, Rosazza

30.000 €

2 locali 80 m2

Figure 19: Real estate opportunities in Rosazza. Source *Idealista*

Agenzia Entrate

Cerca...

Cittadini | Imprese | Professionisti | Intermediari | Enti e PA | L'Agenzia

Ti trovi in: Home / Servizi / Risultato

Banca dati delle quotazioni immobiliari - Risultato

Risultato interrogazione: Anno 2024 - Semestre 2

Provincia: BIELLA

Comune: ROSAZZA

Fascia/zona: Centrale/CENTRO URBANO

Codice di zona: B2

Microzona catastale n.: 1

Tipologia prevalente: Abitazioni di tipo economico

Destinazione: Residenziale

Tipologia	Stato conservativo	Valore Mercato (€/mq)		Superficie (L/N)	Valori Locazione (€/mq x mese)		Superficie (L/N)
		Min	Max		Min	Max	
Abitazioni civili	NORMALE	375	560	L	2,6	3,5	N
Abitazioni di tipo economico	NORMALE	290	435	L	2	2,8	N
Ville e Villini	NORMALE	560	790	L	3,4	4,7	N

- Lo STATO CONSERVATIVO indicato con lettere MAIUSCOLE si riferisce a quello più frequente di ZONA
- Il Valore di Mercato è espresso in Euro/mq riferito alla superficie Netta (N) ovvero Lorda (L)
- Il Valore di Locazione è espresso in Euro/mq per mese riferito alla superficie Netta (N) ovvero Lorda (L)
- La presenza del carattere asterisco (*) accanto alla tipologia segnala che i relativi Valori di Mercato o di Locazione sono stati oggetto di rettifica.
- Per le tipologie Box, Posti auto ed Autorimesse non risulta significativo il diverso apprezzamento del mercato secondo lo stato conservativo
- Per la tipologia Negozi il giudizio O/ N /S è da intendersi riferito alla posizione commerciale e non allo stato conservativo dell'unità immobiliare

Legenda

- Il Valore di Mercato è espresso in Euro/mq riferito alla superficie Netta (N) ovvero Lorda (L)
- Il Valore di Locazione è espresso in Euro/mq per mese riferito alla superficie Netta (N) ovvero Lorda (L)

Nella tipologia è indicato lo stato di conservazione e manutenzione che può assumere i seguenti valori:

- Ottimo
- Normale
- Scadente

Figure 20: Database of the value of the houses. Source: Agenzia delle Entrate

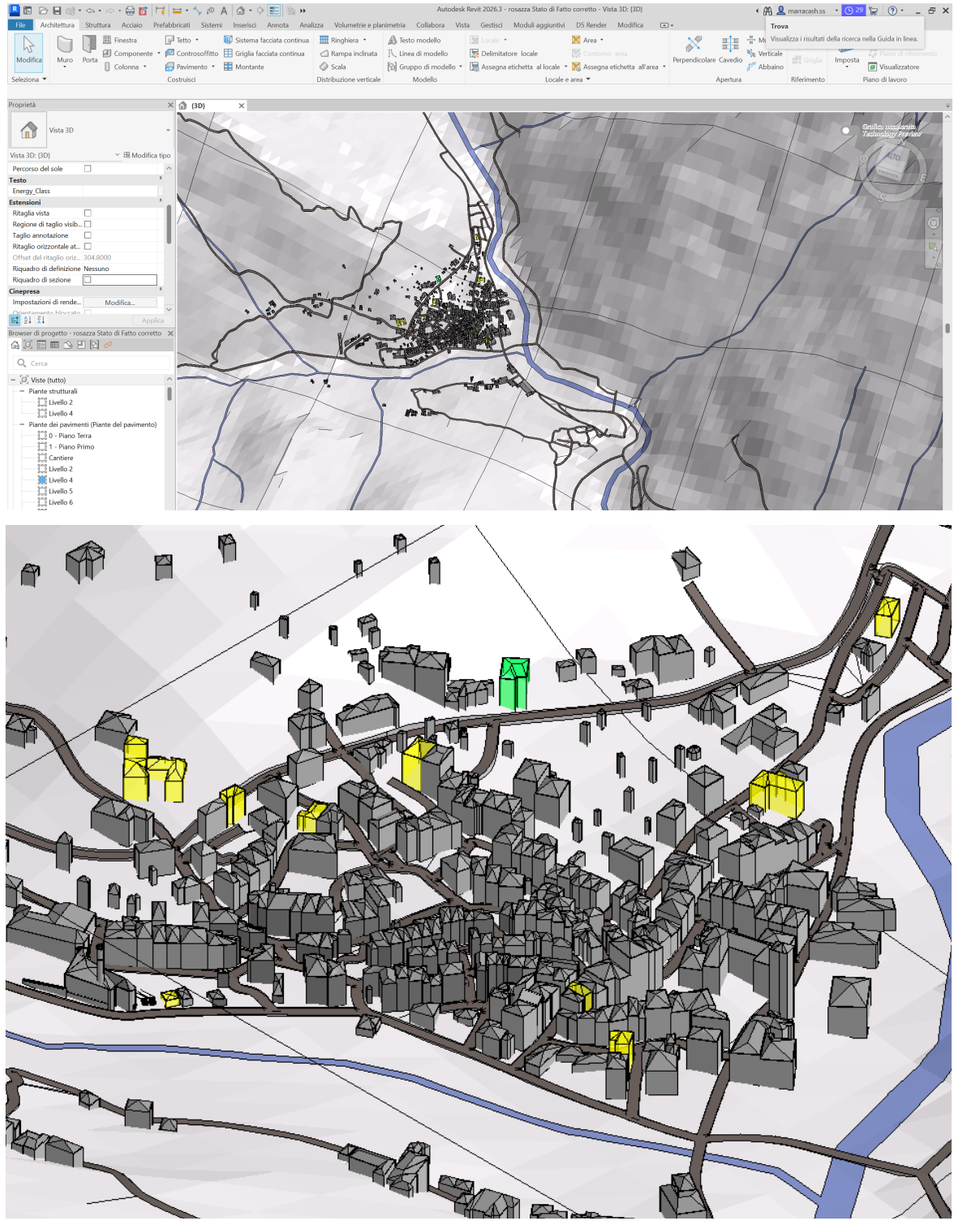


Figure 21: Real Estate opportunities in Rosazza. Green color: auction - Yellow: on sale. By Salvatore Tartaglia

The Real Estate model:

BIM-based massing model, that was developed in order to represent the building stock and later to relate it to the energy performances of the buildings analyzed, was further readapted for real estate purposes with the aim of showing which are the buildings of the town object of selling, renting or auctions.

It was assigned a distinct colour to those buildings that are effectively present on the market. In this way, the BIM model does not only describe the physical and energy characteristics of the village, but also integrates information about market availability and investment opportunities.

Regarding the opportunities of BeB and short rents in Rosazza, but also in the surrounding towns of Adorno Micca, Piedicavallo and in the city of Biella, represent an emerging opportunity for people who want to invest in the real estate sector.

In recent years the Biellese has recorded a steady increase in tourist arrivals and overnight stays, with 2024 and 2025 data showing growth rates above the regional average.

This positive trend is accompanied by a strong expansion of the accommodation offer, especially in non-hotel structures.

Figure 22 represent the BeBs that are present in the website Air Bnb. Despite the number of opportunities that were only 2 in September 2025, in reality by comparing this number with the other announcements present in different platforms, the number increase.

In addition, after a survey done in the town in November 2025, the presence of advertisements shows clearly that the opportunities are higher and the number is increasing more and more.

In fact, as reported by some residents of the mountain town, some new investors are coming in the town.

Some of them arrive to spend a weekend or even more (two weeks - one month)

Figure 22: BeB offerts in Rosazza. Source *Air BnB*

come there to work. The majority of them have the possibility of working from home, but a relevant problem that is present is linked to the internet connection.

In fact, as Alberto Rosazza refers, the internet quality is bad and the possibility of working on remote is challenging.

Without mobile connection and the hotspot made mobile, the pubblic internet network is not optimized and represent an aspect to improve in order to give a bigger value to the town and to guarantee a wider range of tourist that can be attracted by the place.

The most famous renting opportunity in Rosazza is Affittacamere " la Valligiana" that presents its opportunity of renting to the tourists with the following message: "If you want to fully enjoy the tranquillity, a cosy guesthouse is available in the old schools of the village of Rosazza. You have access to a garden and a wonderful view from the rooms".

SELECTION OF THE MOST REPRESENTATIVE BUILDING OF THE URBAN PATTERN. 3.3
CASE STUDY OF THE CONSERVATIVE RESTORATION

In order to identify the most representative building to develop an architectural project of conservative restoration with the introduction of technological devices, that can satisfy the restrictions imposed by the legislation and the urban codes, it was necessary to investigate the most common tipologes and height of the buildings in Rosazza. The data collected from Geoportale Arpa Piemonte [018], have been transferred into the scheme of the *table 2* at the end of this page. The urban planning and the transformation of Rosazza are regulated by the Municipal General Regulatory Plan, that establishes the typology of interventions and the rule of construction in the town and sets the different types of buildings based on their function. Considering the data extracted form Geoportale Arpa for Rosazza, that mapped the plan of the town and the elevations of the buildings, the majority of houses presents and elevation of around 3 meters or 11 meters 8 in both cases they are 67 houses). The pilot building object of the restoration is located in the centre of the town, with coordinates: (45.676045 latitude, 7.976643 longitude). It is a very peculiar case of the site considering that it is located in the centre of the urban fabric, among the narrow streets and the very close buildings, that were built in this was in order to be more efficient in terms of insulation from the cold temperatures. Moreover, the buildings of Rosazza, usually share and external wall with the other buildings next to them. The reason behind it is the necessity to save material and decrease the prices. The following table collects the data of the height of the buildings in the town, based on Geoportale Arpa. The previous BIM model of Rosazza for the energetic and

	Residential areas
3 m	67
4 m	24
5 m	18
6 m	21
7 m	14
8 m	29
9 m	44
10 m	61
11 m	67
12 m	62
13 m	30
14 m	15
15 m	5
16 m	4
17 m	2
18 m	0
19 m	0
20 m	0
30 m	1
Unknown	10
TOTAL	473

Table 2: total number of buildings and their height in Rosazza, according to Geoportale Arpa. By S. Tartaglia

Photo 14: Pilot building highlighted. By Salvatore Tartaglia

economical analysis has been designed according to values of height collected.
The pilot building, which has a total height of around 12 meters, is located very close to the Casa museo dell'alta Valle Cervo.
The analysis of the degradation of the facade (photo 14) highlights the presence of evident degradation of the plaster, mainly caused by high humidity due to water infiltration through the walls and direct raining with part of plaster completely detached and many wall interventions done during the years, in order to try to hide or contrast the problem of humidity.
In addition to this, the original drainpipe has been covered in some parts with the use of cement. The restoration of the facade is required to be coherent with the context. Moreover, the balconies highlight the presence of substantial degradation of the slab caused by high levels of water filtration that may highlight the absence of a insulation layer in the balconies, that appear also not flat but with some small slopes, the application of an insulation layer is required.
Regarding the railings, they appear oxidized, as consequence of lost of paint and antioxidant paints. The removal of the rusted iron and the application of a new antioxidant paint is required, trying to keep the same colour of the original railing.
Furthermore, the doors and windows are quite old and overused. They should be replaced with more insulating windows without compromising the original aesthetic and without introducing new materials (such as PVC windows that are not allowed).
With regards to the contact with the ground, there is an evident sign of rising humidity, which highlight the necessity to intervene with a ventilated foundation slab.

Photo 15: small courtyard in front of the building. By Salvatore Tartaglia

Photo 16. By Salvatore Tartaglia

Photo 17. Street view by Kamil Talar

CONSERVATIVE RESTORATION OF THE PILOT BUILDING 3.4
TYPOLOGY OF THE INTERVENTIONS ALLOWED:
URBAN AND TECHNOLOGICAL FRAMEWORKS

Once the identification of the pilot and distinctive building has been completed, the project seeks to determine the necessary interventions, taking into account the energy assessments already conducted and the objective of enhancing the building's overall value.

Conversely, in the case of the buildings in Rosazza, the restoration process is challenged by the limited availability of technical information, which in some instances is entirely lacking. Indeed, to successfully retrofit the town's buildings, it is essential to understand the stratigraphy of the existing walls. However, in the absence of precise surveys or reliable data either previously collected, documented in the literature, or available online the goal of improving both the energy performance and the architectural quality of the buildings presents significant challenges.

In addition, considering the significant value of the historical architectural heritage of Rosazza, that is one of the most emblematic examples of XIXth century architecture almost perfectly and entirely preserved over the time, and the beauty of the natural landscape, the town is notably protected by the Piano Regolatore Generale (PRG) and the Norme Tecniche di Attuazione (NTA).

In fact, the PRG categorized Rosazza as an historical town with architectural heritage to be preserved.

The consequence is that, all the interventions of restorations undergo a vigorous control in order to be not invasive for the surrounding environment.

Although the legislation imposed strict directives for the restorative interventions, there are some documents that assess the differences in mortar mix and stone density suggest several restoration stages present, but lacking a definitive record of material compatibility evaluations.

For instance, residential row houses display uneven wall thickness and variations in material layering, proposing undocumented rebuilding stages.

Furthermore, for independent villas and country houses: numerous buildings have concealed structural issues, such as, wood decay in roof trusses, necessitating thermal imaging and laser scanning for accurate evaluation.

In these cases of houses that were renovated or modified multiple times, in order to establish which were the original characteristics, professionists can use BIM and 3D laser scanning and Ground Penetrating Radar (GPR) for developing precise digital replicas of historical structures.

These models are capable of visualizing, hidden structural lacks, model retrofitting situations, and monitor material deterioration across time, thus reducing

• **[3]** RESTAURO E RISANAMENTO CONSERVATIVO

"Gli interventi rivolti a conservare l'organismo edilizio e ad assicurare la funzionalità mediante un insieme sistematico di opere che, nel rispetto degli elementi tipologici, formali e strutturali dell'organismo stesso, ne consentano destinazioni d'uso con essi compatibili. Tali interventi comprendono il consolidamento, il ripristino ed il rinnovo degli elementi degli elementi costitutivi dell'edificio, l'inserimento degli elementi accessori e degli impianti richiesti dalle esigenze dell'uso, l'eliminazione degli elementi estranei all'organismo edilizio" (L.R. n°56/77, art. 13).

Gli interventi di restauro e risanamento conservativo sono volti principalmente alla conservazione e alla valorizzazione degli edifici dei quali si intende operare il recupero degli elementi tipologici, architettonici ed artistici, ovvero un adeguamento funzionale, compatibile con i caratteri degli organismi edilizi. Questi interventi non riguardano soltanto gli edifici che, a norma dell'art.24, 4° comma, lettera a), della L.R. n°56/77 sono soggetti esclusivamente a restauro e risanamento conservativo, ma tutti gli edifici per i quali si intende prevedere possibilità di modificazioni dell'organismo edilizio o delle destinazioni d'uso, nel rispetto dei caratteri tipologici, formali e strutturali. É necessario disporre quindi di strumenti normativi il più possibile articolati, adeguati gli uni al rigoroso restauro statico ed architettonico di edifici di pregio, gli altri al recupero funzionale di organismi edilizi aventi o meno interesse storico-artistico o ambientale. Si distinguono pertanto due tipi di intervento:

il restauro conservativo (RC1), finalizzato principalmente alla conservazione, al recupero e alla valorizzazione dei caratteri degli edifici di interesse storico-artistico, architettonico e ambientale.

il risanamento conservativo (RC2),finalizzato principalmente al recupero igienico e funzionale di edifici per i quali si rendono necessari il consolidamento e l'integrazione degli elementi strutturali e la modificazione dell'assetto planimetrico, anche con l'impiego di materiali e tecniche diverse da quelle originarie, purché congruenti con i caratteri degli edifici. Questo tipo di intervento può essere previsto anche per edifici di interesse storico-artistico, individuati dagli strumenti urbanistici ai sensi del citato art. 24, qualora il loro stato di conservazione, i caratteri tipologici ovvero l'esigenza d'uso rendano necessarie modificazioni e integrazioni dell'organismo edilizio;

Il restauro conservativo é rivolto essenzialmente alla conservazione dei caratteri tipologici, strutturali, formali e ornamentali dell'opera e all'eliminazione delle aggiunte e superfetazioni che ne snaturano il significato artistico e di testimonianza storica. Di norma tali interventi devono essere eseguiti con l'impiego di materiali originari e di tecniche specifiche di conservazione e di ricostruzione, secondo i principi della scienza e dell'arte. Gli interventi di restauro e risanamento conservativo possono essere finalizzati anche alla modificazione della destinazione d'uso degli edifici purché la nuova destinazione ammessa sia compatibile con i caratteri tipologici, formali e strutturali dell'organismo edilizio.

Per l'esecuzione di tali interventi é richiesta l'osservanza delle modalità e l'eventuale uso degli strumenti attuativi previsti dalle leggi vigenti, indicate in sintesi dalla presenti norme al Capo VIII agli artt. 21, 22, 23.

Ai fini dell'ammissibilità delle opere e di ulteriori prescrizioni procedurali, si intende integralmente riportata la Circolare Regionale 5/SG/URB del 27.04.84.

Figure 23: NTA guidelines for the town of Rosazza

risks linked to unrecorded building conditions [10].

All the alterations, even if they are not predominant in comparison to the total number of buildings that keep the historical characteristics of the period in which they were built, produce a complication in the process of assessing the possible interventions and improving the energy performances of the buildings. Considering this, careful analyses and interventions need to be performed in order to not compromise the value of the architecture or to damage the buildings that have survived for very long time since their construction in the XIXth century.

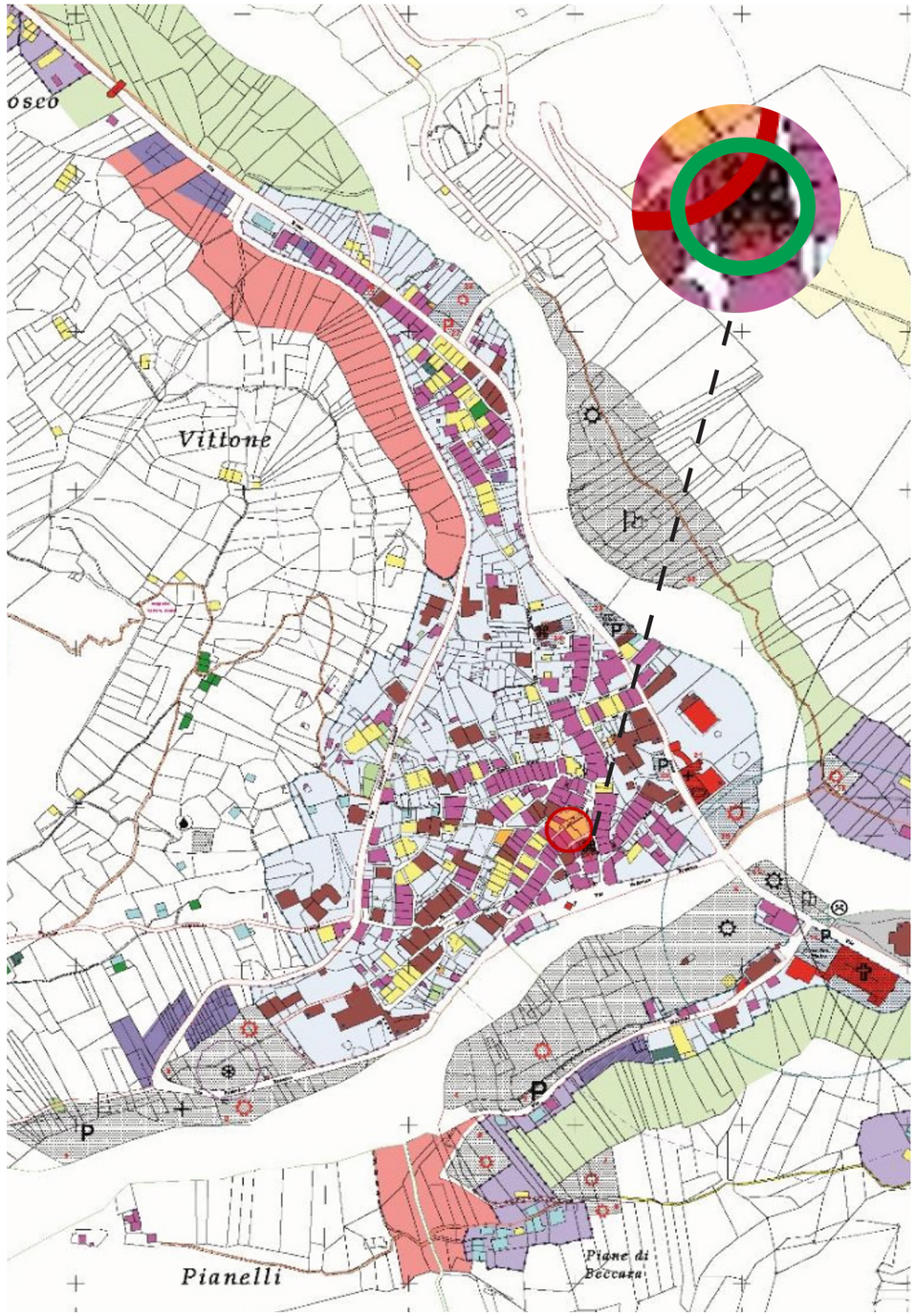


Figure 24: PRG of Rosazza, elaboration by Emilio Brunazzi. Green Circle=pilot project of this thesis. Out of scale

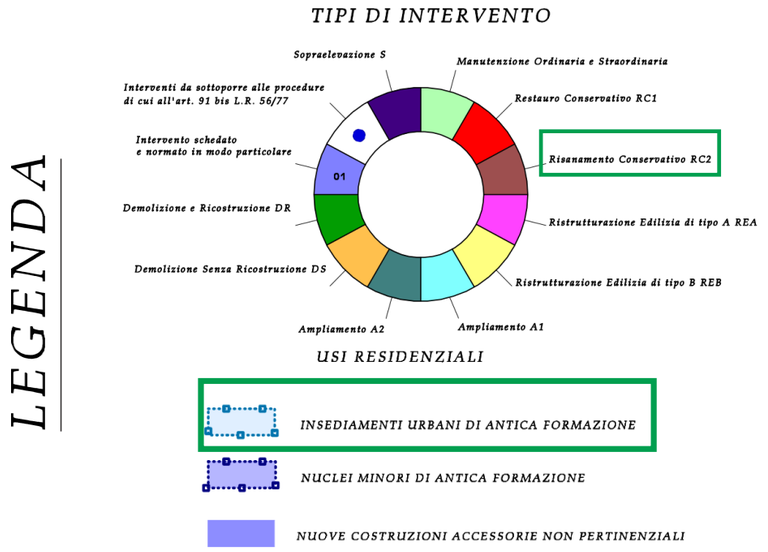


Figure 25: Legend of the PRG of Rosazza, typology of interventions allowed

In the hypothesis of pilot project that is inside the RC2 definition by the general regulatory plan, we could imagine to introduce the following rehabilitation strategies:

1) Improvement of the thermal insulation of the external walls

2) Improvement of the thermal and acoustic insulation of the internal partitions.

3)Introduction of photovoltaic panels

The documents: *L'architettura rurale del G.A.L. Montagne Biellesi. Guida al recupero dell'architettura tradizionale* [20] and *Piano di Governo del Territorio del comune di Arpica* [019], provide the guidelines and the rules to respect for the interventions of rehabilitation and restoration of the houses in the mountains regions, based on the preservation of the history of the architectural heritage and the improvement of the overall conditions of the buildings.

The typology of rehabilitation interventions allowed is reported below, based on the legislation, urbanistic and historical restrictions and frameworks:

Roof (1st design solution)**:**

with regards to the design of the new insulated roof, two solutions are presented and later compared in terms of costs.

The stratigraphies, represented below come form an interpretation of the literature and the technical documents as common insulation strategies for roofs with stone finishing made of "lose". The details of the layers are taken from documents that analyses the architecture of Valle Cervo.

In Rosazza the majority of the houses have stone finishing, as shown in the picture at page 33, but terracotta tiles finishing are also common. In terms of thermal conductivity U, the lose layer and the clay tiles.

Famiglia:	Tetto di base
Tipo:	Insulated Roof 1st tipolgy Rosazza
Spessore totale:	0.4400 (Default)
Resistenza (R):	2.5833 (m²·K)/W
Massa termica:	218.51 kJ/(m²·K)

Strati

	Funzione	Priorità	Materiale	Spessore
3	Sostrato	2	Assi in legno	0.0300
4	Struttura	1	Travetti	0.0500
5	Strato Termico/Camera d'aria	1	Superficie analitica - Supe	0.0500
6	Struttura	1	Travetti	0.0500
7	Sostrato	2	Assi in legno	0.0300
8	Strato Termico/Camera d'aria	2	Isolamento	0.0050
9	Strato Termico/Camera d'aria	2	Water vapour barrier pro	0.0050
10	Sostrato	2	Assi in legno	0.0300
11	Struttura	1	Wood strud (edited)	0.0500
12	Struttura	1	Costane	0.0500
13	Struttura	1	Dormiente (edited)	0.0500

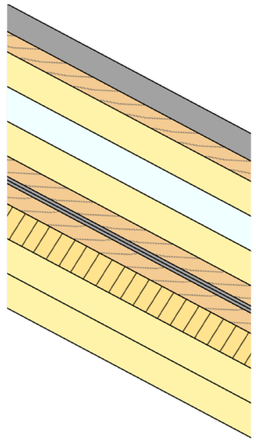
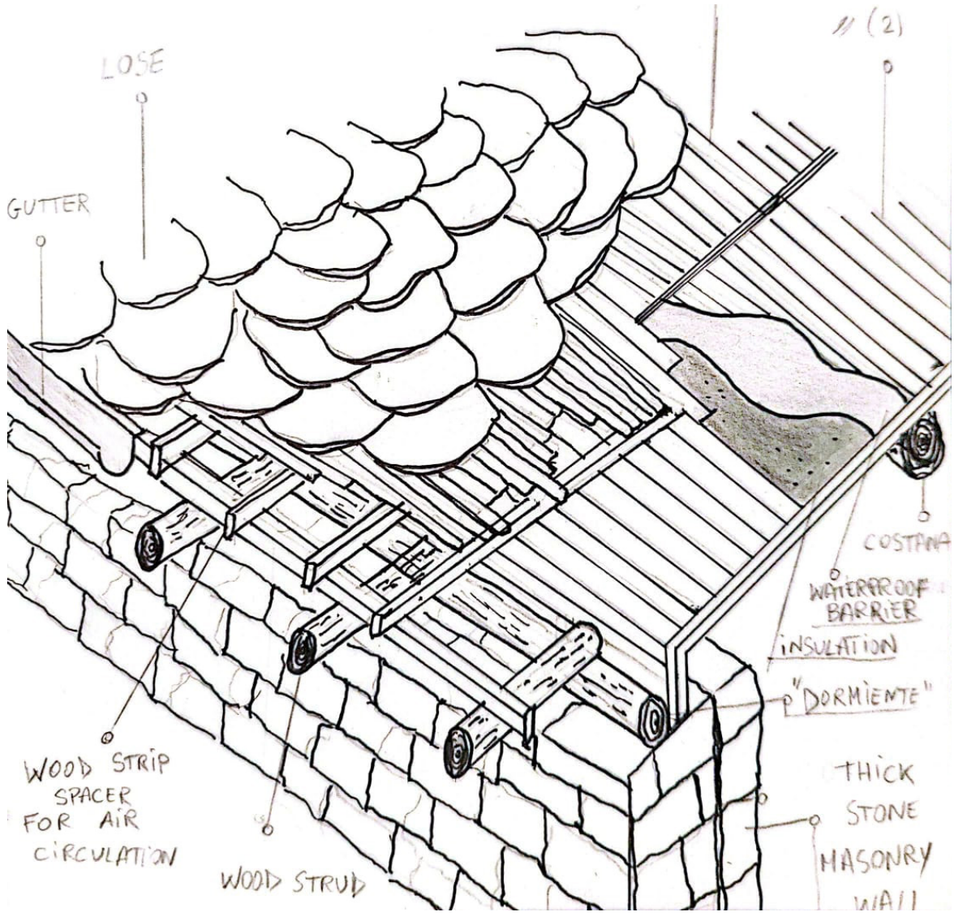


Figure 26: Stratigraphy of the first solution of insulated roof in Revit



Sketch 1: First typology of Insulated Roof. By Salvatore Tartaglia

External and internal walls:

The thermal insulation of the existing external walls is a big concern, considering that a big heat exchange happen through crack or high thermal conductivity materials.

The pilot building presents stone masonry with lime mortar, a typical solution adopted in Rosazza, with an external layer of plaster.

The stone does not have low thermal conductivity and the reasons why historically in the past in was common to have thick walls was not only for the main static reason, to keep a strong and resistant structure, but also to have a big thermal mass that could reduce as much as possible the heat exchange between the inside and outside of the house. Stone masonry with lime mortar is the most common typology in Rosazza.

In order to improve the energy performance of the house and to satisfy the restrictions imposed by the PRG, NTA and the landscape plan, an insulation layer has been applied in the inside of the building, such as the areogel, that guarantee good thermal properties within a thin layer.

The local stone has a thermal conductivity, which is translated into U-values that are:

$2{,}5\ W/m^2K \leq U \leq 3{,}0\ W/m^2K$.

This range of values increase if the masonry is older and presents a higher number of cracks that can create thermal bridges.

The design of the new insulated stratigraphy is characterized by the application of a thermal insulating material made of aerogel panels fixed in a wooden frame.

The external facade is preserved , while the interior the modification is very small, creating an air gap to allow the masonry to “breath” without the production of humidity and mould.

This setup enhances thermal insulation, while preserving the original wall, thanks also to the possibility to assemble and disassemble the system easily, which is crucial in RC2-compliant restoration projects based on the NTA and the PRG.

For the internal walls, it was common to build stone masonries due to the high availability of the stone or in other cases, such as the houses that were renovated subsequently, they were made of bricks or hollow bricks with lime and sand plaster. Obviously, the thickness of internal walls was small compared to the external ones, as consequence of their function because internal walls had the purpose of separating the different rooms and insulated the acoustic noises, so they were not structural elements. For these reasons they were light.

In the pilot building the internal walls are made of bricks and the intervention required regards the introduction of new layers in the stratigraphy, since the demolition of the partitions is not allowed.

The new stratigraphy is made of a 5 mm layer of lime plaster, a 3 mm layer of mineral wool (wood fibers or cork is then analysed) a fiberglass reinforcing mesh of 0.5 mm, the brick masonry and the same layers on the other side of the wall.

Furthermore, the introduction of new bricks is necessary is the case they are cracked or missing.

Ground floor foundations:

A ventilated crawl space is an empty area beneath the ground floor (or foundation floor) that includes a drainage layer (gravel/ draining polystyrene), isolated from the soil by geo-textile and membrane, featuring ventilation openings leading to the outside. The floor (set up for insulation and screed) is placed over the crawl space. The goal is to disrupt the moisture-ground-structure cycle, facilitate air movement, and gather water. The ventilated crawl space reduces rising damp, improves comfort and can limit problems with mould and radon. Useful height of the crawl space: typically 30–80 cm and there should always be a certain slope to allow the water to drain. Based on the RC2 directives of the NTA of Rosazza, it is allowed to realize a ventilated crawl, since the intervention is among the hygienic, functional and, in part, structural restoration of existing buildings, without altering their original type, shape and structure.

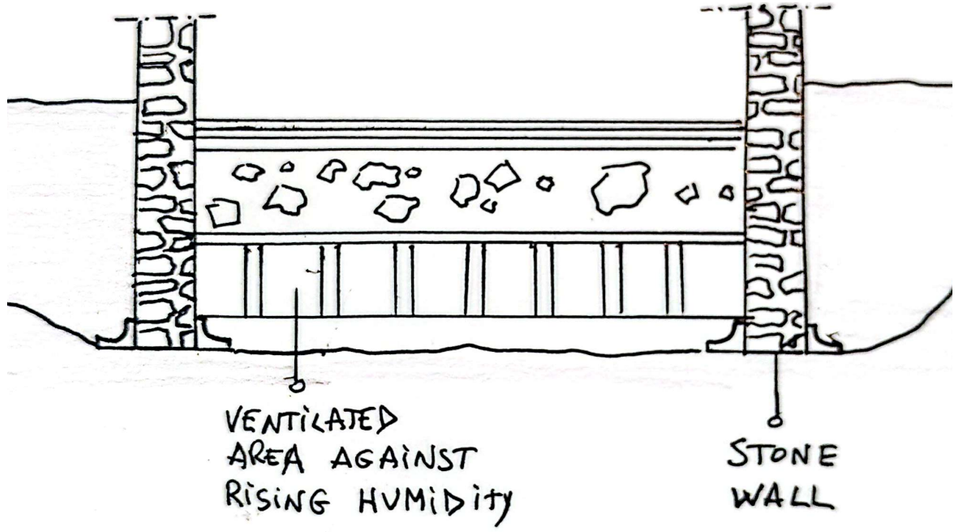
Creating a crawl space involves modifications to the load-bearing structure of the floor: it may require the demolition of the existing floor, changes to the floor level, etc. Essential elements of the original building must not be modified.

The phases for the creation of a ventilated crawl are:

excavation, geotextile and drainage layer (gravel or panels), collection pipes, application of the anti-capillary barrier membrane (if required), casting of floor slab, positioning of insulation (XPS/EPS) and screed, installation of ventilation grilles and inspection hatch, connections to drains and surface finishes and testing.

Staircase:

The wooden stair needs an overall improvement of the structure with the substitution of new wooden steps and the application of neutral paint that can emphasize the aesthetic of the wood and provides brightness to the material, without compromising the original colour.



Sketch 2: Detail of the foundation slab. By Salvatore Tartaglia

Slabs:

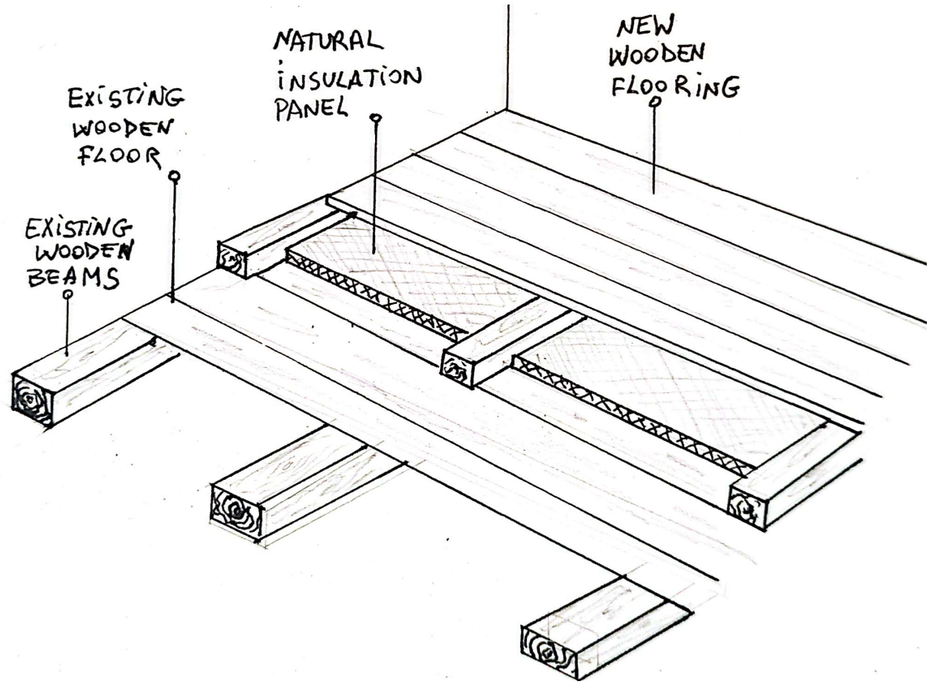
In the energy performance and consumption calculations, all the interior surfaces of a house that do not face the exterior, such as the interior floors, the interior wall are considered as warm surfaces, so they do not impact in the energy exchange inside of the building. While from an energetic point of view the slabs satisfy the requirements, on the other hand the rehabilitation of the floors require a structural reinforcement due to the risk of collapse for old pavements and an acoustic insulation layer.

Famiglia: Pavimento
Tipo: Solaio Rosazza 1 edited
Spessore totale: 0.2800 (Default)
Resistenza (R): 1.6111 (m²·K)/W
Massa termica: 133.40 kJ/(m²·K)

Strati

	Funzione	Priorità	Materiale	
1	Finitura 1	4	Assi in legno	0.0400
2	**Contorno del nucleo**		**Strati sopra ripiegatura**	**0.0000**
3	Struttura	1	Travetti	0.0600
4	Strato Termico/Camera d'aria	1	Isolamento	0.0600
5	**Contorno del nucleo**		**Strati sotto ripiegatura**	**0.0000**
6	Finitura 1	4	Assi in legno	0.0400
7	Struttura	5	Costane	0.0800

Figure 27: Stratigraphy of the slab in Revit. By Salvatore Tartaglia



Sketch 3: insulation of the house floors. By Salvatore Tartaglia

Figure 30: Representation of the slab. source:

Windows:

Single-glazed wooden windows, typically equipped with shutters but missing double-glazing and weather-sealed frames, leading to cold drafts and loss of heat. The new double-glazed windows has a low-E coatings and are filled with argon gas, minimizing
heat conduction and enhancing insulation. The U-value can decrease form a range of values of 5 to 6 W/m²K to has been noticeably decreased to 1.0 - 1.6 W/m²K, improving indoor thermal comfort while allowing adequate daylight values. The SHGC (solar heat gain coefficient) is currently optimized to 0.35 - 0.45, balancing solar heat capture while avoiding excessive overheating.

A crucial aspect is that the new windows still have a wooden frame to try to preserve the original aesthetic of the building, especially in the facade.

The window replacement thus represents a key step in improving the overall energy performance of the building. The use of wooden frames with low-E, argon-filled double glazing significantly reduces heat losses, enhances thermal insulation, and improves indoor comfort during colder months. At the same time, retaining the timber frame allows the intervention to respect the architectural identity of the original façade, maintaining the building's historic character and visual harmony within the existing urban context.

This approach strikes a careful balance between energy efficiency and aesthetic preservation, combining advanced building technologies with traditional materials. The adoption of high-performance glazing also ensures adequate daylight penetration, minimizing the need for artificial lighting and enhancing visual comfort.

Overall, this solution strengthens the building's environmental sustainability while preserving its material authenticity and cultural value, aligning with the broader principles of conservative restoration very important in the historical city of Rosazza, as already mentioned before, where it is important also to respect the restrictions given to the existing size of the windows.

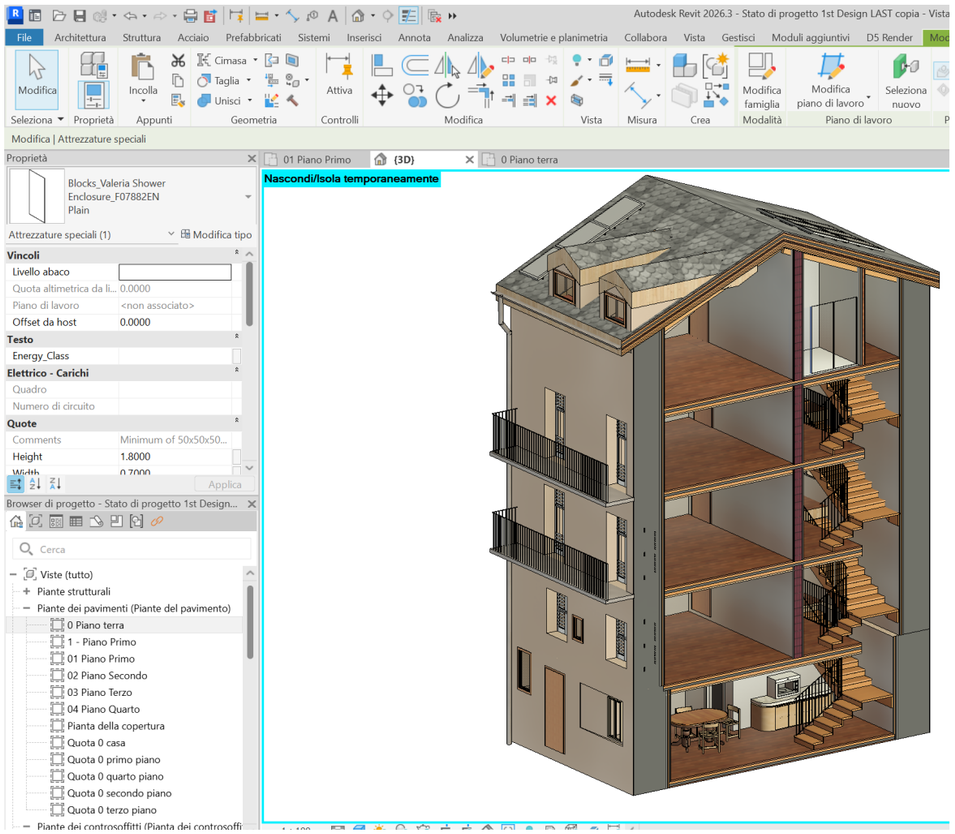


Figure 28: 3D model of the house sectioned. By Salvatore Tartaglia

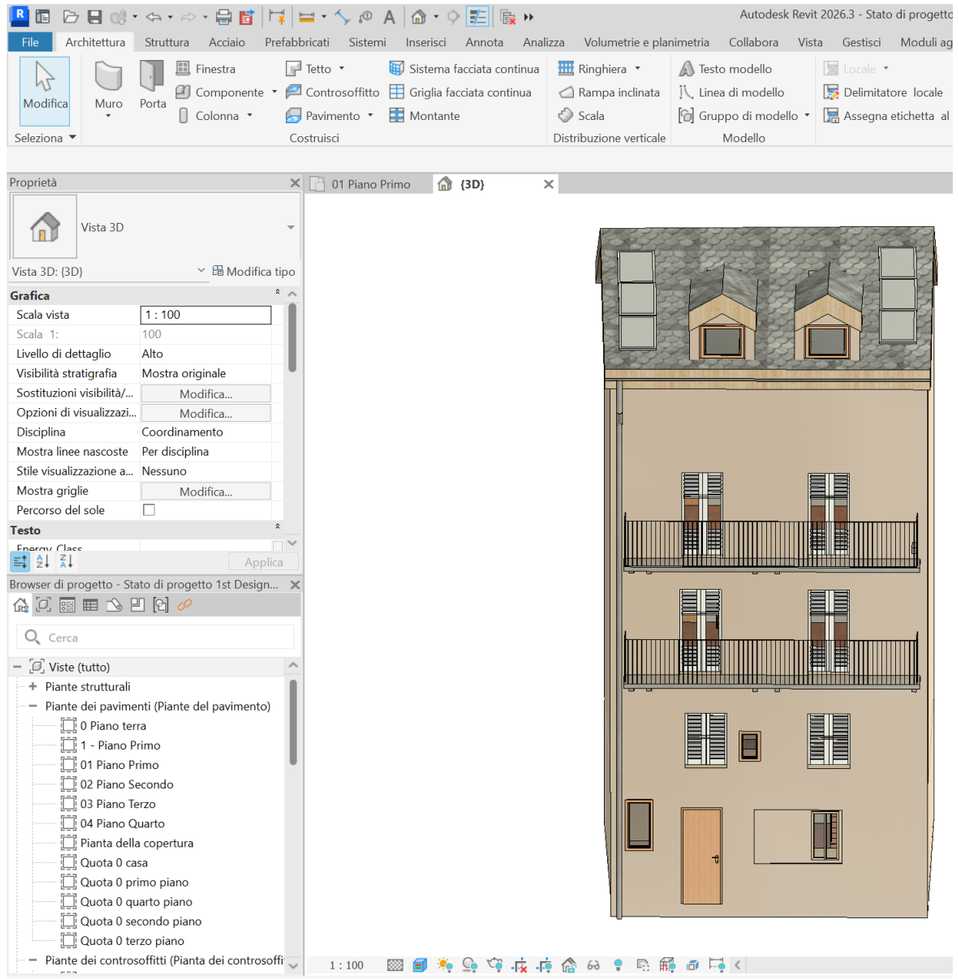


Figure 29: 3D model of the front facade facing the west. By Salvatore Tartaglia

Technological systems:

After a survey and assessment of the conditions of the technological systems, in the assumption that the new property needs a complete substitution of the system, considering that old buildings generally need a replacement of the systems due to safety reasons and legal directives. The investors who want to renovate the house, need to consider also the cost related to these systems. The necessary interventions on the technological systems related to the rehabilitation of the house are related to: 1) elettrical system 2) water and sanitation system 3) heating system 4) wastewater treatment plant system.

1) **Elettrical system:**

At first it is recommended a complete review of current electrical systems to ensure they comply with present regulations. When setting up new systems, it is not recommended to create holes in the masonry, but instead to place the appropriate conductors into skirting boards or other components located along the perimeter of the spaces. This is due to the fact that penetrating stone masonry buildings, apart from being expensive, may result in instability in the masonry and separations among the stones, potentially resulting in additional deterioration of the whole structure. A suitable approach is to use dark coloured or white tailored plastic pipes, with a diameter beginning at 15 mm, fixed to the wall with metal or plastic wall anchors and brackets that link junction boxes and switches positioned externally as well. Another common replacement system is to pass the cables through the PVC skirting board channel, and to connect all the cables of the TV, phone et cetera, in the meters and junction boxes.

2) **Water and sanitation system:**

A general inspection of current systems is advised to detect any failures or operational inefficiencies that might lead to damaging water leaks. The water distribution pipes need to be replaced if required. For sanitary installations, whether it's a replacement or a new setup, it is advisable to utilize standardized components, like sanitary units that consolidate supply and drainage pipes, lightweight modular walls, ideally covered in wood, that do not burden the current floors, along with visible systems. The presence of sanitary facilities also demands proper ventilation of the space : where the provision of sanitary facilities also necessitates proper ventilation of the space: where the project's location prevents natural ventilation, making it essential to implement ventilation. through mechanical airflow in the spaces.

3) **Heating system:**

In an conservative renovation project, there are two different alternatives that can be considered regarding the optimization of the heating system. The installation of natural gas or GPL systems featuring boilers is permitted, as long as technical standards, distances from networks/pipelines, and legal obligations for these systems are met. Wood-fired heating can also be reinstated (biomass boilers); however, this must now utilize contemporary, low-emission certified generators and adhere to local regulations regarding emissions and combustion times.

RISANAMENTO CONSERVATIVO

Elenco delle opere ammesse riferite ai principali elementi costitutivi degli edifici

PRINCIPALI ELEMENTI COSTITUTIVI DEGLI EDIFICI	OPERE AMMESSE
FINITURE ESTERNE (intonaci, rivestimenti, tinteggiatura, infissi, elementi architettonici e decorativi, pavimentazioni, manto di copertura)	Ripristino, sostituzione e integrazione delle finiture, da eseguirsi con l'impiego di materiali e tecniche congruenti rivolte alla valorizzazione dei caratteri dell'edificio e alla salvaguardia di elementi di pregio. Non é comunque ammesso l'impoverimento dell'apparato decorativo.
ELEMENTI STRUTTURALI (fondazioni, strutture portanti verticali e orizzontali, scale e rampe, tetto)	Ripristino e consolidamento statico degli elementi strutturali. Qualora ciò non sia possibile a causa delle condizioni di degrado, sono ammesse la sostituzione e la ricostruzione degli stessi, limitatamente alle parti degradate o crollate. É ammesso il rifacimento di parti limitate di muri perimetrali portanti qualora siano degradate o crollate, purché ne sia mantenuto il posizionamento originale. Devono essere impiegati materiali e tecniche congruenti con i caratteri dell'edificio, senza alterazione della tipologia e salvaguardando gli elementi di pregio. Per documentate necessità statiche o per mutate esigenze d'uso, sono ammesse modeste integrazioni degli elementi strutturali, purché siano impiegati elementi e tecniche compatibili con i caratteri dell'edificio. É esclusa, comunque, la realizzazione di nuovi orizzontamenti, qualora comporti aumento della superficie utile. Non sono ammesse alterazioni volumetriche, planimetriche e di sagoma, ad eccezione di quelle relative all'installazione degli impiantii tecnologici, né alterazioni delle pendenze delle scale, delle quote degli orizzontamenti e delle quote d'imposta e del colmo delle coperture.
MURATURE PERIMETRALI, TAMPONAMENTI E APERTURE ESTERNE	Ripristino e valorizzazione dei prospetti, nella loro unitarietà. Parziali modifiche sono consentite nel rispetto dei caratteri originari. É ammesso il rifacimento di parti limitate di tamponamenti esterni, qualora siano degradate o crollate, purché ne sia mantenuto il posizionamento.
TRAMEZZI ED APERTURE INTERNE	Ripristino e valorizzazione degli ambienti interni, con particolare attenzione per quelli caratterizzati dalla presenza di elementi architettonici e decorativi di pregio, quali: volte, soffitti e pavimenti, affreschi. Sono ammesse, per mutate esigenze funzionali e d'uso, modificazioni dell'assetto planimetrico che non interessino gli elementi strutturali, ad eccezione della realizzazione ed eliminazione di aperture nei muri portanti. Sono ammesse le aggregazioni e le suddivisioni delle unità immobiliari purché non alterino l'impianto distributivo dell'edificio, con particolare riguardo per le parti comuni.
FINITURE INTERNE (tinteggiatura, intonaci e rivestimenti, controsoffitti, pavimenti, infissi, elementi architettonici e decorativi)	Ripristino di tutte le finiture. Qualora ciò non sia possibile, é ammesso il rinnovamento e la sostituzione delle stesse con l'impiego di materiali e tecniche congruenti con i caratteri dell'edificio e tendenti alla valorizzazione degli elementi di pregio, con particolare riguardo alle parti comuni. Non é comunque ammesso l'impoverimento dell'apparato decorativo.
IMPIANTI ED APPARECCHI IGIENICO-SANITARI	Realizzazione ed integrazione degli impianti e dei servizi igienico-sanitari, nel rispetto delle limitazioni di cui ai punti precedenti.
IMPIANTI TECNOLOGICI E RELATIVE STRUTTURE E VOLUMI TECNICI (impianti elettrici, di riscaldamento e condizionamento, del gas, idrici, di scarico, di sollevamento e depurazione di rifiuti liquidi, solidi ed aeriformi)	Installazione degli impianti tecnologici e delle relative reti. I volumi tecnici devono essere realizzati all'interno dell'edificio e non devono comportare alterazioni dell'impianto strutturale e distributivo dello stesso. Per quanto concerne gli edifici a destinazione produttiva (industriale, artigianale, agricola) e commerciale, é ammessa l'installazione di impianti tecnologici, nonché la realizzazione degli impianti e delle opere necessari al rispetto della normativa sulla tutele degli inquinamenti e sull'igienicità e la sicurezza degli edifici e delle lavorazioni, purché non comportino un aumento delle superfici utili di calpestio. I volumi tecnici relativi possono essere realizzati all'esterno dell'edificio purché non configurino un incremento della superficie utile destinata all'attività produttiva o commerciale. Al fine del mantenimento dei caratteri compositivi dei prospetti, si esclude l'alterazione delle facciate prospicienti spazzi pubblici o di uso pubblico attraverso questo tipo di intervento.

Table 3: PRG of Rosazza, tipology of interventions allowed for buildings classified as RC2.

TECHNICAL PRE-FEASIBILITY STUDY 3.5
FOR THE CONSTRUCTION AND TRANSPORTATION
OF THE MATERIALS IN THE WORKING SITE.

One of the most relevant challenges to face in order to restore buildings that are present in mountainous urban contexts such as Rosazza, with small streets and very dense urban fabrics, is the access to the building and the transportation of the materials during the phases of construction and dismantling. In the following images, during a survey in Rosazza , the main accesses to the house to restore have been highlighted. The main street that allow to reach the town is Via Roma, that presents a total width of around 7 meters, which allows the transition of heavy trucks and buses. In the northern part of Via Roma, nearby the bar *La strettoia*, there is a shrinkage in the street, which does not allow two vehicles to pass at the same time. In the picture it is possible to understand how an urban bus managed by Atap, with the size of 10,70 m x 2,55 m x 3,16 m finds some difficulties to pass in the street, which means that the maximum width acceptable to cross all *Via Roma* in direction Biella-Rosazza-Piedicavallo is of 2,55 meters. The pilot project, that is located in the southern part of the town, does not require to pass from the shrinkage in the street. It is therefore necessary to reach the building through via Roma, via Federico Rosazza, via Garibaldi, via Pietro Micca and via Moro Mosca. Specifically, for the interventions required for restoring the building, the majority of them can be realized by carrying by hand the materials with wheelbarrows, to carry the scaffolding, the drills etc. In other cases, e.g. for transporting heavy materials, it is therefore possible to use craine that can be parked in via F. Rosazza due to the considerable width of the street. In fact, as shown in the view number 2, the truck that has

View of the bus and via Roma shrinkage. Width:2,55m width of the shrinkage in the street≈2,65m. By Salvatore Tartaglia.

View of the truck for the interventions in the river. Width≈2,70m width of via Roma≈4,20m. By Salvatore Tartaglia.

Via Roma. Width≈7,00 m

Via Federico Rosazza. Width≈4,20 m

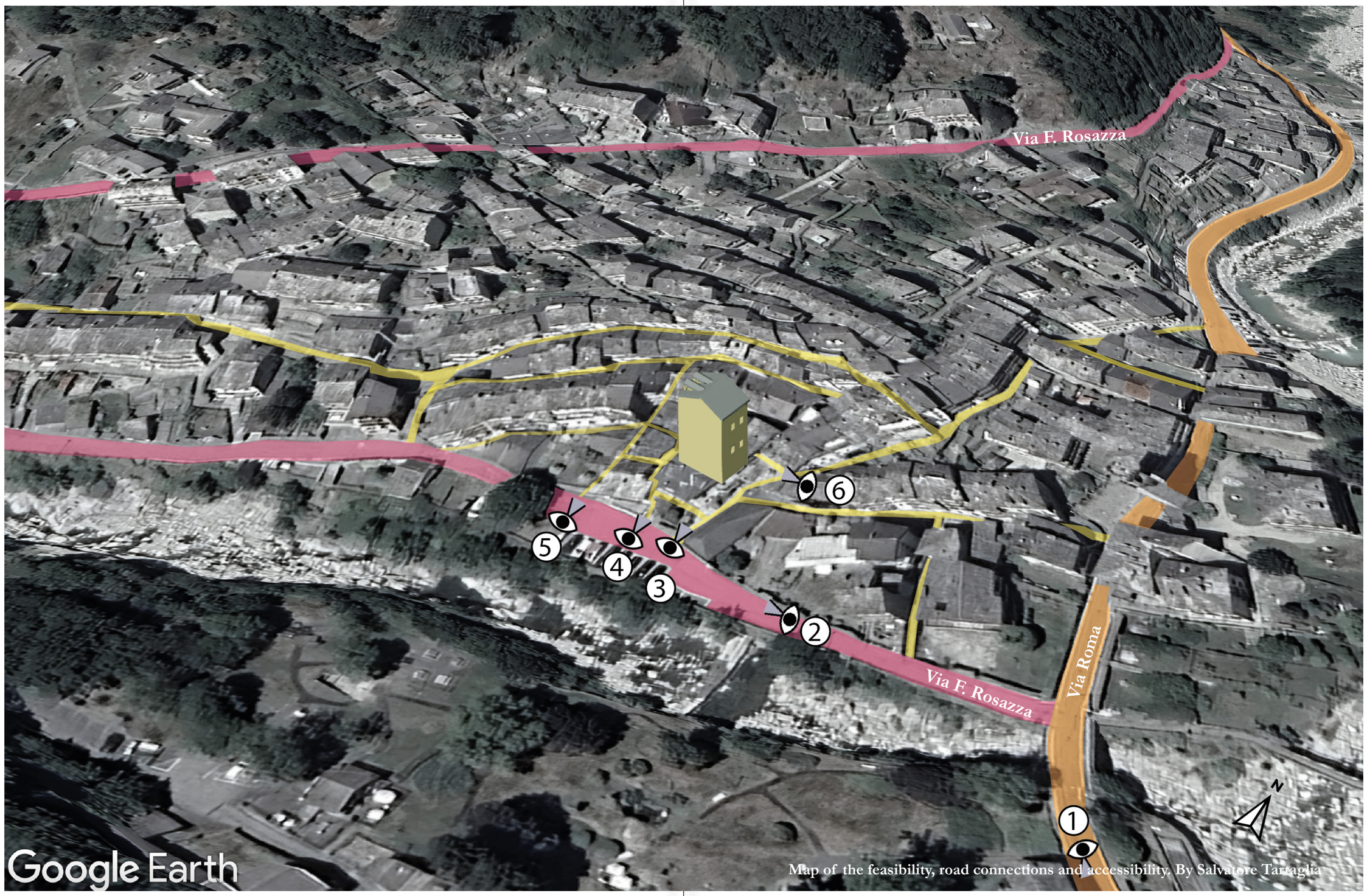
Via Garibaldi. Width≈1,5 m

Via Pietro Micca. Width≈1,20 m

Via Moro Mosca. Width≈1,20 m

Via Pietro Micca. Width≈2,40 m

Collage 1: Points of view and widths of the streets that give access to restore the pilot building. By Salvatore Tartaglia.



Map of the feasibility, road connections and accessibility. By Salvatore Tartaglia

3.6 ECONOMICAL ESTIMATION OF THE COSTS FOR THE RESTORATION PROJECT:

TIME AND PRECISION OPTIMIZATION THROUGH:
INTEROPERABILITY REVIT - PRIMUS IFC DCF

Performing an economical estimation of the costs of an architectural and engineering project, both in the case of new constructions, restoration of the built environment or for hypothesis of future works, has always been difficult in terms of time used, frequent errors occurred in the calculation of the prices of the interventions and also in the quantity of materials, typology of interventions et cetera. Traditionally the procedure at the base of the cost estimation, after the period of the hand-made drawings, consisted on the design and elaboration of CAD drawings and later, the calculation of the quantities, such as: areas, distances, and volumes were obtained from Autocad and then multiplied, added to the regional price list. For instance, in order to obtain the price for the construction of a specific insulated external wall for an energetic retrofitting intervention in a building in Biella, normally the professionists calculate the total area of the external wall, with the command "Area" from the different CAD files representing the facade of the building, subtracting the total areas of the voids in the walls, occupied by the windows, adding all the total areas for each "net" wall facade and multiplying it for the specific price of the material taken in consideration from the list of prices of the Regional Price List of Piedmont, in this example. All the other works considered to be implemented in all the phases of the design and construction of the retrofitting project, represents many other cost voices. Later on, the computations obtained from Autocad, become the input in software such as Primus DCF by Acca, that calculates the price of the works and relate it to the exact work to be performed, taken from the price list of the Region considered. It appears evident that the traditional method is not only out of date, but also very time and effort consuming with high probability of mistakes. Furthermore, considering that during the design and construction phases, several times happens to modify the characteristics of the project, with this traditional methodology, the change of the sizes of a wall in the CAD file, implies a big amount of computational transformations and high numbers of errors, with final mistakes in the costs estimation. Considering this, the use of BIM and some plug-in interconnected with BIM software, has revolutionised the sector of economical estimations. Further improvements of interoperability and optimization of the costs will be implemented, although the 5D dimension of BIM (Cost Analysis) already needs more optimization.

For the purposes of this master's thesis, the interoperability between Revit and Primus IFC by Acca was tested.

As already introduced before, Revit by Autodesk is probably the most used software for working with building information modelling methodology, followed by Archicad by Graphisoft. It presents a very large library of plug-ins and tools that can be used for enhancing very different analysis of the projects, such as solar, thermal and energetic analysis. Since it is a software for BIM, Revit works with families, so 3D entities such as the family of the 40 cm external walls, that presents a very broad list of informations inside. For example, by selecting a the specific family of 40 cm walls, it is possible to edit layer by layer each material used in the wall (plaster, insulation layer, mortar, hollow tiles etc.) and each layer presents different characteristics such as, for the hollow tiles, their own thermal conductivity, their price per element of brick or per square meter, the colour of the layer, the hatch for 2D technical representation and also characteristic for future renders.

Understanding this characteristic is important for a right comprehension of the way BIM and plug-ins, such as Primus IFC by ACCA, work. Primus IFC is one of the most used and optimized software for calculating the bill of quantities and keep the control and computation of the public and private works, especially in Italy. It is provided by ACCA company and allows not only to obtain the bill of quantities, but also the price list of the regions considered, that can be downloaded directly from the ACCA website, in different extensions (.pdf, .dcf, .xls) and the informations regarding the progress of the works.

It is important to specify that only a good level of detail of the BIM project can produce accurate bill of quantities, a metric calculation performed at a low LOD is characterised by families with approximate geometries, will present some values within the parameters that may be inaccurate compared to those of the real objects. [21]

The initial page of Primus presents the classic sheet for the bill of quantities, where the user can put the voices of costs or download all the voices from internet. It is also possible to define super categories, categories, sub categories of costs, costs for works for element, works for measures and discounts or subtractions for specific works performed or materials used. These and other functions of Primus DCF can be listed in the list below: Primus DCF software by Acca allows to:

- Create new documents to insert voices of costs or create new voices of costs.
- Upload other personal list of costs.
- Save lists of costs and used them again as reference for future projects.
- Insert new more detailed description, measures and costs for prices.
- Insert schemes, photos, drawings to explain better the specific voices of costs related. - Sharing the personal lists of costs with e-mails and some other features.

In Revit there is the possibility to create a bill of quantities without the use of any plug-in, but this approach requires more time and also needs very high precision, since It works with the creation of abacus inside the software (lists of items with high precision of informations inside), based on the single families used in the project. On the other hand, with Primus IFC the precision for the cost estimation is higher.

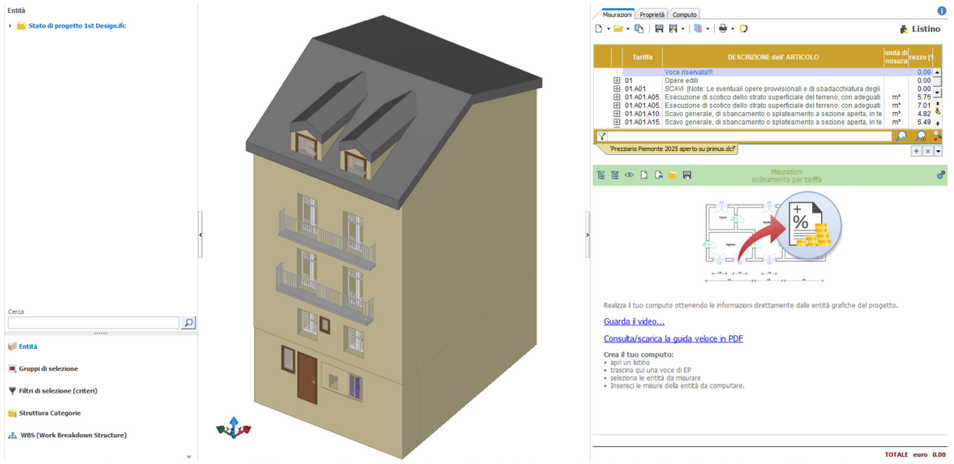


Figure 31: BIM model imported in Primus Acca ifc with the regional price list. By Salvatore Tartaglia

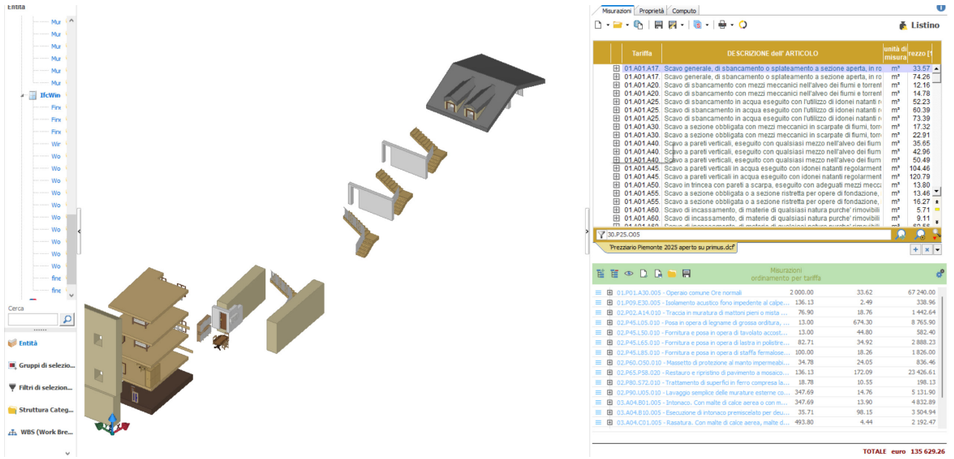


Figure 32: Voices of costs and exploded axonometry view. By Salvatore Tartaglia

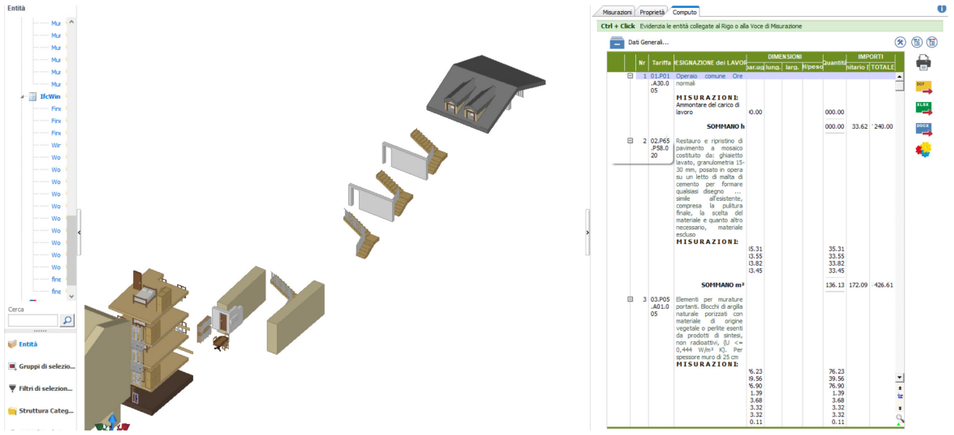


Figure 33: Preview of the final bill of quantites in Primus Acca IFC. By Salvatore Tartaglia

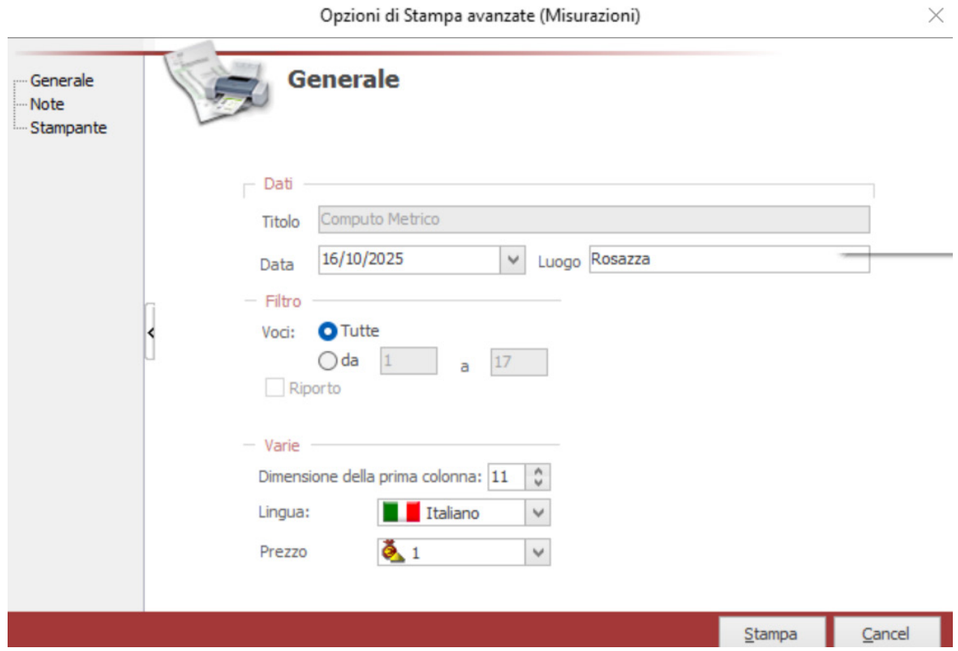


Figure 34: Preview of the exporting and translation options in Primus Acca IFC. By Salvatore Tartaglia

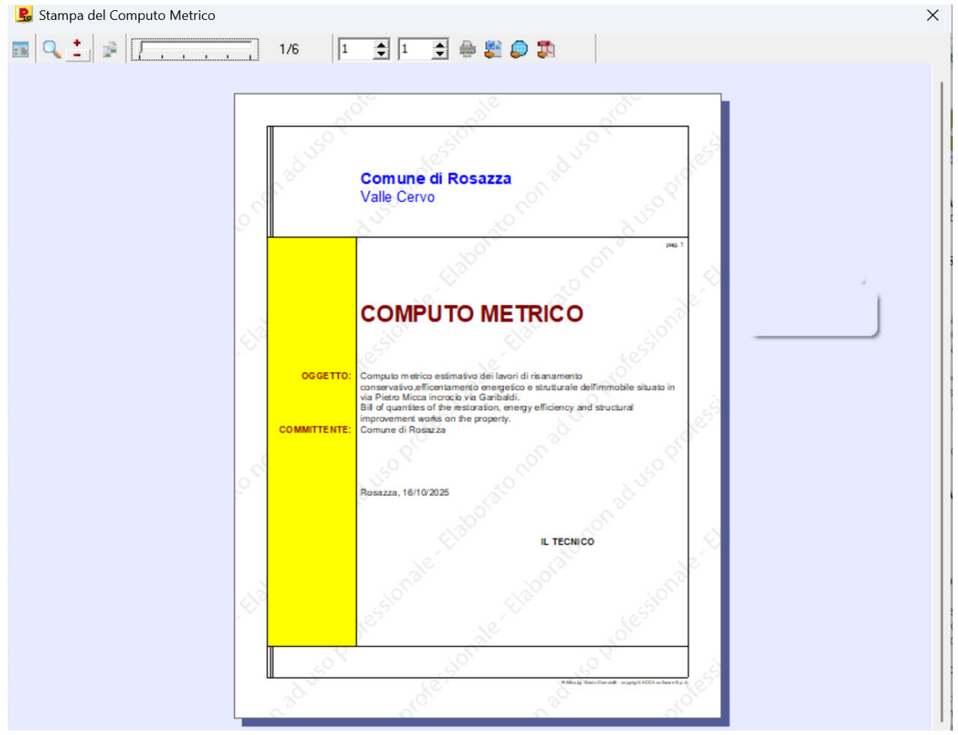


Figure 35: Final Preview of the bill of quantites in Primus Acca IFC. By Salvatore Tartaglia

OPTIMIZATION OF PROJECT COST CALCULATION IN THE PRESENCE OF DESIGN VARIATIONS 3.7

It is very common during the design and construction phases to face the problem of the *in-progress changes* (the so called *variante in corso d'opera*) that represent a change in the decision making due to the presence of a new problem, not considered before. In these cases it is even more evident the how the use of BIM and interoperability can help the professionists to save time and work with precision [020].

In fact, considering the unexpected introduction of photovoltaic panels, the BIM model of the house in Revit has been updated.

Consequentially, the model was exported from Revit and the procedure took only 2 minutes. The next step is to open the previous Primus file that embedded the old version of the project and the bill of quantities.

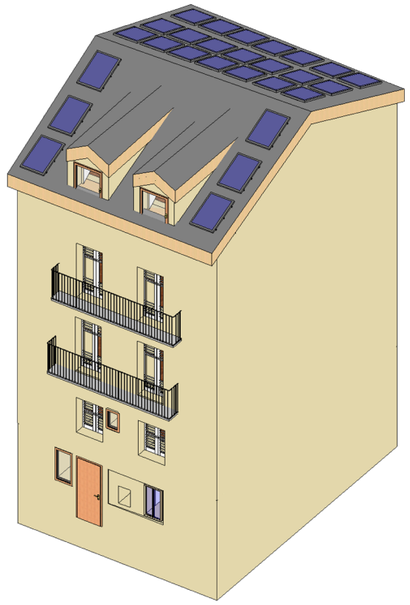


Figure 36: BIM model of the house: 2 nd design optimization. By Salvatore Tartaglia

Primus IFC offers the possibility of a live synchronization between the BIM model and the bill of quantities, which means that, if the BIM model is updated with the substitution of some elements, such as new walls or a different typology of window, inside the menù of Primus IFC there is the possibility to update the model and the economical estimation of the costs by selecting the option *edit IFC* and import the new IFC file (figure 37). A new window will pop up and allow the user to select the folder and the new IFC file (figure 38). After the model is updated, a report is shown and it represents all the entities that have been introduced or removed in the new file (Figure 39).

This process requires in total less than two minutes for the case study analysed in this thesis and allows to control with ease all the families introduced or removed in the project.

A further final step to do is the selection of the photovoltaic panels in the new model of Primus and the association of their relative new voice of costs. The cost item of PV panels embed also the costs of fixing the panels.

This happens only in the *in-progress changes* cases in which there is the necessity to

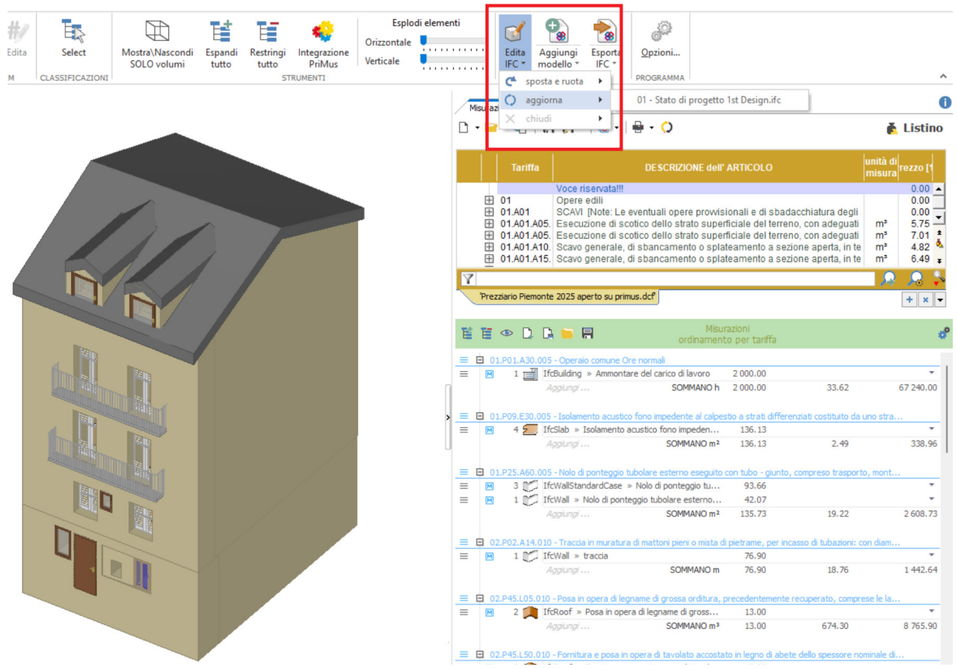


Figure 37: Procedure for synchronizing the updated project in Primus Acca IFC. By Salvatore Tartaglia

introduce new families in the project. In the following images, the model of the house has been updated with the introduction of a relevant number of photovoltaic panels that covered the entire roof, in order to highlight the procedure.

In this case the final result of the economical analysis is a total cost of €197'272,21 (figure 40).

The figure 41 represents a more realistic scenario in which a total number of 12 photovoltaic panels have been introduced. In this case, the model and the computation were updated immediately and the final

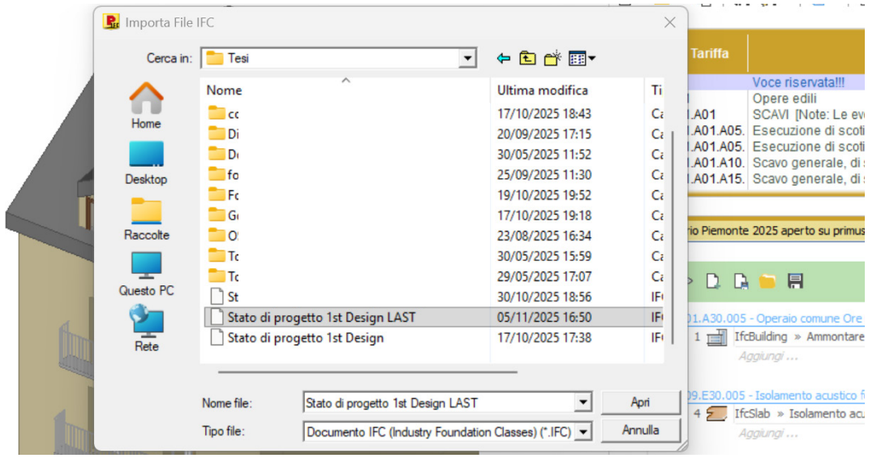


Figure 38: Selection of the updated model in the folders of the pc. By Salvatore Tartaglia

Report Aggiornamento file IFC

Aggiunto "(IfcBuildingElementProxy) 72_Watt_Solar_Panel_13856:72_Watt_Solar_Panel_13856:222461 | 1000185"
Aggiunto "(IfcBuildingElementProxy) 72_Watt_Solar_Panel_13856:72_Watt_Solar_Panel_13856:222640 | 1000186"
Aggiunto "(IfcBuildingElementProxy) 72_Watt_Solar_Panel_13856:72_Watt_Solar_Panel_13856:222730 | 1000187"
Aggiunto "(IfcBuildingElementProxy) 72_Watt_Solar_Panel_13856:72_Watt_Solar_Panel_13856:224809 | 1000188"
Aggiunto "(IfcBuildingElementProxy) 72_Watt_Solar_Panel_13856:72_Watt_Solar_Panel_13856:224878 | 1000189"
Aggiunto "(IfcBuildingElementProxy) 72_Watt_Solar_Panel_13856:72_Watt_Solar_Panel_13856:224953 | 1000190"
Aggiunto "(IfcBuildingElementProxy) 72_Watt_Solar_Panel_13856:72_Watt_Solar_Panel_13856:226828 | 1000191"
Aggiunto "(IfcBuildingElementProxy) 72_Watt_Solar_Panel_13856:72_Watt_Solar_Panel_13856:226881 | 1000192"
Aggiunto "(IfcBuildingElementProxy) 72_Watt_Solar_Panel_13856:72_Watt_Solar_Panel_13856:226952 | 1000193"
Aggiunto "(IfcBuildingElementProxy) 72_Watt_Solar_Panel_13856:72_Watt_Solar_Panel_13856:226995 | 1000194"
Aggiunto "(IfcBuildingElementProxy) 72_Watt_Solar_Panel_13856:72_Watt_Solar_Panel_13856:227095 | 1000195"
Aggiunto "(IfcBuildingElementProxy) 72_Watt_Solar_Panel_13856:72_Watt_Solar_Panel_13856:227140 | 1000196"
Aggiunto "(IfcBuildingElementProxy) 72_Watt_Solar_Panel_13856:72_Watt_Solar_Panel_13856:227207 | 1000197"
Aggiunto "(IfcBuildingElementProxy) 72_Watt_Solar_Panel_13856:72_Watt_Solar_Panel_13856:227304 | 1000198"
Aggiunto "(IfcBuildingElementProxy) 72_Watt_Solar_Panel_13856:72_Watt_Solar_Panel_13856:227377 | 1000199"
Aggiunto "(IfcBuildingElementProxy) 72_Watt_Solar_Panel_13856:72_Watt_Solar_Panel_13856:227428 | 1000200"
Aggiunto "(IfcBuildingElementProxy) 72_Watt_Solar_Panel_13856:72_Watt_Solar_Panel_13856:227513 | 1000201"
Aggiunto "(IfcBuildingElementProxy) 72_Watt_Solar_Panel_13856:72_Watt_Solar_Panel_13856:227614 | 1000202"
Aggiunto "(IfcBuildingElementProxy) 72_Watt_Solar_Panel_13856:72_Watt_Solar_Panel_13856:227683 | 1000203"
Aggiunto "(IfcBuildingElementProxy) 72_Watt_Solar_Panel_13856:72_Watt_Solar_Panel_13856:227744 | 1000204"
Aggiunto "(IfcBuildingElementProxy) 72_Watt_Solar_Panel_13856:72_Watt_Solar_Panel_13856:228109 | 1000205"
Aggiunto "(IfcBuildingElementProxy) 72_Watt_Solar_Panel_13856:72_Watt_Solar_Panel_13856:228188 | 1000206"
Aggiunto "(IfcBuildingElementProxy) 72_Watt_Solar_Panel_13856:72_Watt_Solar_Panel_13856:228267 | 1000207"
Aggiunto "(IfcBuildingElementProxy) 72_Watt_Solar_Panel_13856:72_Watt_Solar_Panel_13856:228328 | 1000208"
Aggiunto "(IfcBuildingElementProxy) 72_Watt_Solar_Panel_13856:72_Watt_Solar_Panel_13856:228397 | 1000209"
Aggiunto "(IfcBuildingElementProxy) 72_Watt_Solar_Panel_13856:72_Watt_Solar_Panel_13856:228486 | 1000210"
Aggiunto "(IfcBuildingElementProxy) 72_Watt_Solar_Panel_13856:72_Watt_Solar_Panel_13856:228573 | 1000211"

'Computo metrico design 1.1.DIFC' (C:\Users\marra\OneDrive\Desktop\Tesi\)

Figure 39: Report of the new entities introduced in the computation. By Salvatore Tartaglia

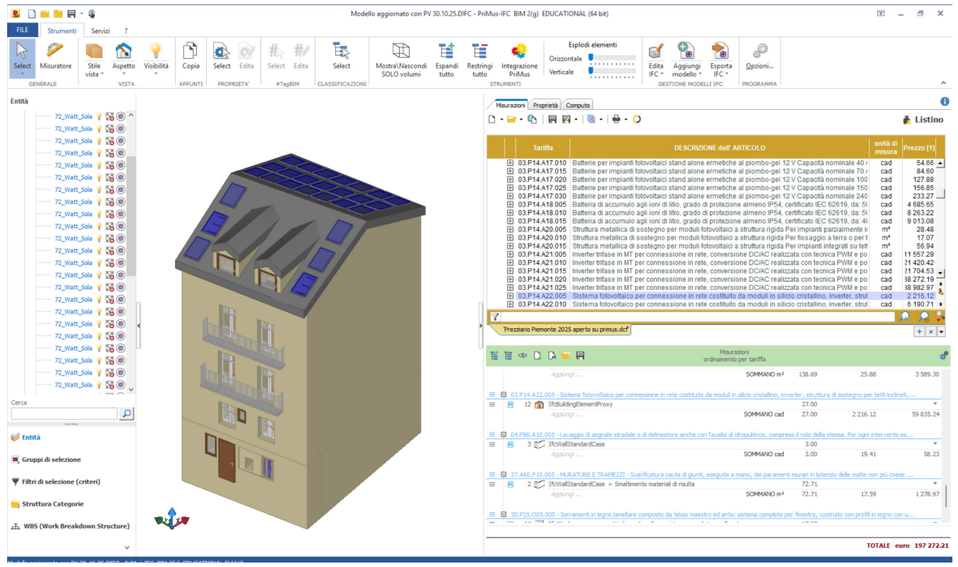


Figure 40: Updated version of the project imported in Primus. By Salvatore Tartaglia

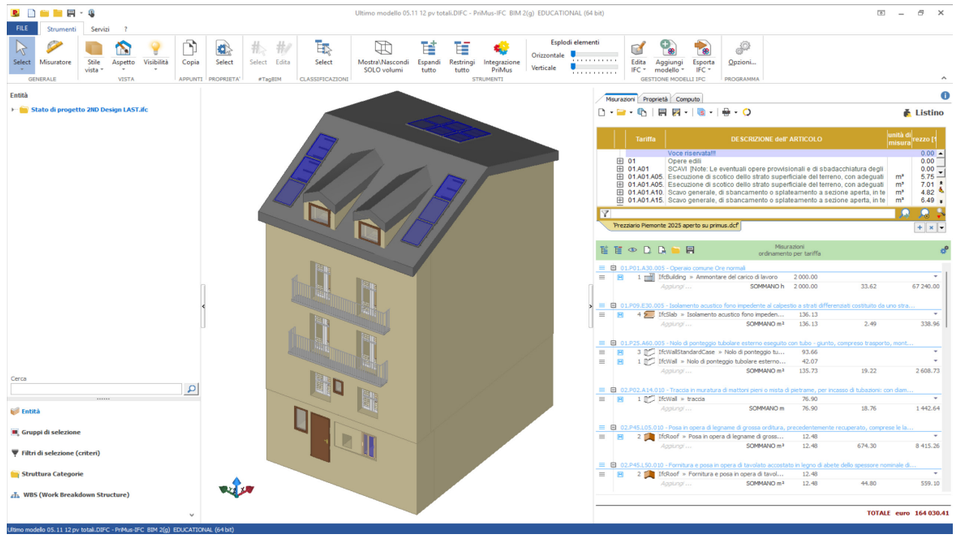


Figure 41: 2nd design optimization with less PV panels with the updated bill of quantities. By Salvatore Tartaglia

				1,71	
				1,71	
				1,71	
				1,11	
				1,11	
				1,11	
				1,11	
				1,08	
				1,08	
	SOMMANO m²			20,09	352,18	7'075,30
21 01.P01.A30. 005	Operaio comune Ore normali Ammontare del carico di lavoro			2'000,00		
	SOMMANO h			2'000,00	33,62	67'240,00
22 03.P14.A22. 005	Sistema fotovoltaico per connessione in rete costituito da moduli in silicio cristallino, inverter, struttura di sostegno per tetti inclinati, esclusi cavi di connessione, quadri DC e AC con dispositivi di protezione ed interfaccia Impianto parzialmente integrato complanare alla falda, potenza 1 kWp			12,00		
	SOMMANO cad			12,00	2'216,12	26'593,44
	Parziale LAVORI A MISURA euro					164'030,41
	T O T A L E euro					164'030,41

Data, 05/11/2025

Il Tecnico

A RIPORTARE

COMMITTENTE: Comune di Rosazza [Computo design aggiornato con 12 pv panles.dcf (C:\Users\marra\OneDrive\Desktop\Tesi\computo\) v.1/22]

Figure 42: Final bill of quantities with the total cost of the conservative restoration. By Salvatore Tartaglia

Comune di Rosazza
Valle Cervo

pag. 1

COMPUTO METRICO

OGGETTO: Computo metrico estimativo dei lavori di risanamento conservativo,efficentamento energetico e strutturale dell'immobile situato in via Pietro Micca incrocio via Garibaldi.
Bill of quantites of the restoration, energy efficiency and structural improvement works on the property.

COMMITTENTE: Comune di Rosazza

Data, 05/11/2025

IL TECNICO

PriMus by Guido Cianciulli - copyright ACCA software S.p.A.

Figure 43: Bill of quantities exported from Primus IFC in PDF (cover page). By Salvatore Tartaglia

Num.Ord. TARIFFA	DESIGNAZIONE DEI LAVORI	DIMENSIONI par.ug.	lung.	larg.	H/peso	Quantità	IMPORTI unitario	TOTALE
	RIPORTO							
	LAVORI A MISURA							
1 01.P09.E30.005	Isolamento acustico fono impedente al calpestio a strati differenziati costituito da uno strato di agglomerato di sughero naturale e un cartone bivermiculizzato sulle due facce del peso di g/m² 800 in tre strati, con sughero spessore mm 1					35,31 33,55 33,82 33,45		
	SOMMANO m²					136,13	2,49	338,96
2 01.P25.A60.005	Nolo di ponteggio tubolare esterno eseguito con tubo - giunto, compreso trasporto, montaggio, smontaggio, nonchè ogni dispositivo necessario per la conformita' alle norme di sicure ... voro e sottopiani da compensare a parte (la misurazione viene effettuata in proiezione verticale). Per i primi 30 giorni					20,78 51,93 20,95 42,07		
	SOMMANO m²					135,73	19,22	2'608,73
3 02.P02.A14.010	Traccia in muratura di mattoni pieni o mista di pietrame, per incasso di tubazioni: con diametro fino a 5 cm Rete/collettori di raccolta (tubi di raccolta acque) Traccia in muratura di mattoni pieni o mista di pietrame					76,90		
	SOMMANO m					76,90	18,76	1'442,64
4 02.P45.L05.010	Posa in opera di legname di grossa orditura, precedentemente recuperato, comprese le lavorazioni necessarie per il riutilizzo					6,15 6,33		
	SOMMANO m³					12,48	674,30	8'415,26
5 02.P45.L50.010	Fornitura e posa in opera di tavolato accostato in legno di abete dello spessore nominale di 3 cm, posato su preesistente orditura in legno					6,15 6,33		
	SOMMANO m²					12,48	44,80	559,10
6 02.P45.L65.010	Fornitura e posa in opera di lastra in polistirene espanso, conforme alla norma UNI EN 13163 e alla marcatura CE, tipo EPS 150, presagomata per sottocoppo o sottotegola, tipo "term ... con pari caratteristiche, dello spessore fino a 10 cm, comprensiva di listellatura per il fissaggio della lastra stessa					69,71 6,15 6,33		
	SOMMANO m²					82,19	34,92	2'870,07
7 02.P45.L85.010	Fornitura e posa in opera di staffa fermalose in rame di sezione fino a 20x400x3 mm, completa di chiodi					100,00		
	SOMMANO cad					100,00	18,26	1'826,00
	A RIPORTARE							18'060,76

COMMITTENTE: Comune di Rosazza

Figure 44: Bill of quantities exported from Primus IFC in PDF (first page). By Salvatore Tartaglia

cost is equal to € 164'030,41 with a total saving in the expense in the reduction of the photovoltaic panels from € 58'835,24 to € 26'593,44 and with a saving of € 33'241,80.
For the purposes of this master's degree thesis, as already specified before, the accuracy of the model of the house is not very high, which means that the LOD (level of details) is medium.
As consequence of this, the economical analyses of costs is not very accurate as well.
The reasons behind this choice come from the impossibility to access in the interior part of the building, so It was not possible to do a survey and to establish the exact interventions to perform. In addition, the aim of the thesis is to present a method of intervention with BIM, interoperability and real estate analyses in order to forecast sustainable architecture and revitalize abandoned, semi-abandoned towns and friction spaces inside the cities or

metropolis (such as specific neighborhood of big cities).
Considering both the aim of the thesis and the typology of calculation of costs, that is a pre-feasibility economical study, it appears evident that some specific cost items may lack in this analysis but can be implemented in the future, after a survey of the existing building and with more detailed data regarding the construction companies, the taxes and other voices of costs evaluated in the executive phase.

Num.Ord. TARIFFA	DESIGNAZIONE DEI LAVORI	DIMENSIONI				Quantità	IMPORTI	
		par.ug.	lung.	larg.	H/peso		unitario	TOTALE
	RIPORTO							18´060,76
8 02.P60.O50. 010	Massetto di protezione al manto impermeabile costituito da una cappa di calcestruzzo confezionato in cantiere o preconfezionato, spessore fino a 5 cm, completo di rete elettrosaldata, maglia 10x10 cm					34,78		
	SOMMANO m²					34,78	24,05	836,46
9 02.P65.P58.0 20	Restauro e ripristino di pavimento a mosaico costituito da: ghiaietto lavato, granulometria 15-30 mm, posato in opera su un letto di malta di cemento per formare qualsiasi disegno ... simile all'esistente, compresa la pulitura finale, la scelta del materiale e quanto altro necessario, materiale escluso					35,31 33,55 33,82 33,45		
	SOMMANO m²					136,13	172,09	23´426,61
10 02.P80.S72.0 10	Trattamento di superfici in ferro compresa la preparazione del fondo intesa come asportazione delle parti di ossido in fase di distacco mediante semplice spazzolatura: con vernici convertitrici: su superfici lisce (misurate vuoto per pieno)							
	(lung.=0,5000*1,0000)		0,50			0,50		
	(lung.=4,203064*1,0000)		4,20			4,20		
	(lung.=0,489982*1,0000)		0,49			0,49		
	(lung.=0,5000*1,0000)		0,50			0,50		
	(lung.=4,203064*1,0000)		4,20			4,20		
	(lung.=0,489982*1,0000)		0,49			0,49		
	SOMMANO m²					10,38	10,55	109,51
11 02.P80.S72.0 10	Trattamento di superfici in ferro compresa la preparazione del fondo intesa come asportazione delle parti di ossido in fase di distacco mediante semplice spazzolatura: con vernici convertitrici: su superfici lisce (misurate vuoto per pieno)					1,68 1,68 1,68 1,68 1,68		
	SOMMANO m²					8,40	10,55	88,62
12 02.P90.U05. 010	Lavaggio semplice delle murature esterne con idropulitrice a bassa pressione senza uso di detergenti					20,78 51,93 20,95 24,17 28,28 79,41 42,07 80,10		
	SOMMANO m²					347,69	14,76	5´131,90
13 03.A04.B01. 005	Intonaco. Con malte di calce aerea o con malte di calce idraulica NHL EN 459-1. Esecuzione di intonaco su rinzaffo o di intonaco di fondo, su pareti verticali e orizzontali interne ... , pozzolana e sabbia silicea in granulometria 0 a 3,5 mm, più acqua q.b. Resa ~16 kg/m² per ogni centimetro di spessore.					20,78 51,93 20,95 24,17 28,28		
	A RIPORTARE					146,11		47´653,86

COMMITTENTE: Comune di Rosazza

Figure 45: Bill of quantities exported from Primus IFC in PDF (second page). By Salvatore Tartaglia

In addition to this, an additional 15% of the total cost calculated has been added in order to predict eventual extra costs in the executive phase and to fix eventual cost items that have not been evaluated in the bill of quantities.

Typically, the extra percentage that is accounted follows a range of 5% to 15%, but in this case the higher value was chosen in order to stay in a safer situation from the economical point of view, which means that in case of extra costs, the final

Num.Ord. TARIFFA	DESIGNAZIONE DEI LAVORI	DIMENSIONI				Quantità	IMPORTI	
		par.ug.	lung.	larg.	H/peso		unitario	TOTALE
	RIPORTO					146,11		47´653,86
						79,41 42,07 80,10		
	SOMMANO m²					347,69	13,90	4´832,89
14 03.A04.B10. 005	Esecuzione di intonaco premiscelato per deumidificazione, a base di calce idraulica naturale (Natural Hidraulic Lime)NHL 5 esente da cemento, fibrata con legno di canapa frantumato ... astare con sola acqua pulita. I supporti devono essere stabili, resistenti e puliti. Applicato a macchina. Spessore 4 cm					4,21 11,28 10,11 10,11		
	SOMMANO m²					35,71	98,15	3´504,94
15 03.A04.C01. 005	Rasatura. Con malte di calce aerea, malte di calce idraulica NHL EN 459-1 o malte di argilla. Esecuzione di rasatura su arriccio o intonaco di fondo, su pareti verticali e orizzont ... 0-0,6 mm, più acqua q.b. Resa ~1,3 kg/m² per ogni millimetro di spessore. Prezzo al metro quadrato per 1 mm di spessore.					20,78 20,78 51,93 51,93 20,95 20,95 24,17 24,17 28,28 28,28 79,41 42,07 80,10		
	SOMMANO m²					493,80	4,44	2´192,47
16 03.P01.A01. 015	Pozzolana. Esente da sostanze eterogenee. Non contaminata da agenti radioattivi. Rossa micronizzata Granulometria 0,06mm.					20,38		
	SOMMANO kg					20,38	0,54	11,01
17 03.P05.A01. 005	Elementi per murature portanti. Blocchi di argilla naturale porizzati con materiale di origine vegetale o perlite esenti da prodotti di sintesi, non radioattivi, (U <= 0,444 W/m² K). Per spessore muro di 25 cm					20,78 51,93 20,95 0,51 42,07 0,33 1,06 1,06		
	SOMMANO m²					138,69	25,88	3´589,30
18 04.P86.A10. 005	Lavaggio di segnale stradale o di delineatore anche con l'ausilio di idropulitrice, compreso il nolo della stessa. Per ogni intervento eseguito					3,00		
	SOMMANO cad					3,00	19,41	58,23
	A RIPORTARE							61´842,70

COMMITTENTE: Comune di Rosazza

Figure 46: Bill of quantities exported from Primus IFC in PDF (third page). By Salvatore Tartaglia

cost of the investment should be lower of the one that has been calculated. The extra cost of 15% of the total accounts for € 24'604,50. The total cost is equal to: €164'030,41 (investment for the restoration) + € 24'604,50 (additional 15% of cost) + € 20'000 (hypotetyc price of the house that needs to be renovated). €164'030,41 + € 24'604,50 + € 20'000 €= € 208.634,91.

Num.Ord. TARIFFA	DESIGNAZIONE DEI LAVORI	DIMENSIONI par.ug.	lung.	larg.	H/peso	Quantità	IMPORTI unitario	TOTALE
	R I P O R T O							61˙842,70
19 27.A60.F10. 005	MURATURE E TRAMEZZI - Scarificatura cauta di giunti, eseguita a mano, dei paramenti murari in laterizio delle malte non più coese e rese instabili dal tempo, con attrezzo metallico ... a e la preparazione del giunto atto a ricevere la successiva stilatura e quant'altro occorre per dare il lavoro ultimato					20,78 51,93		
	SOMMANO m²					72,71	17,59	1˙278,97
20 30.P25.O05. 000	Serramenti in legno lamellare composto da telaio maestro ed anta: sistema completo per finestre, costruito con profili in legno con un grado di umidità del 10/12% con certificazion ... 1 m2] In legno di pino (Pinus Sylvestris) con tecnologia finger jointing - Finestra fissa; di superficie fino a 2,0 m²					1,08 1,35 0,65 1,11 1,35 1,11 1,71 1,71 1,71 1,71 1,11 1,11 1,11 1,11 1,11 1,11 1,08 1,08		
	SOMMANO m²					20,09	352,18	7˙075,30
21 01.P01.A30. 005	Operaio comune Ore normali Ammontare del carico di lavoro					2˙000,00		
	SOMMANO h					2˙000,00	33,62	67˙240,00
22 03.P14.A22. 005	Sistema fotovoltaico per connessione in rete costituito da moduli in silicio cristallino, inverter, struttura di sostegno per tetti inclinati, esclusi cavi di connessione, quadri DC e AC con dispositivi di protezione ed interfaccia Impianto parzialmente integrato complanare alla falda, potenza 1 kWp					12,00		
	SOMMANO cad					12,00	2˙216,12	26˙593,44
	Parziale LAVORI A MISURA euro							164˙030,41
	T O T A L E euro							164˙030,41

Data, 05/11/2025

Il Tecnico

A R I P O R T A R E

COMMITTENTE: Comune di Rosazza [Computo design aggiornato con 12 pv panles.def (C:\Users\marra\OneDrive\Desktop\Tesi\computo\) v.1/22]

Figure 47: Bill of quantities exported from Primus IFC in PDF (third page). By Salvatore Tartaglia

3.8 ECONOMICAL AND FINANCIAL ANALYSIS: SCENARIOS OF INVESTMENTS FOR SELLING AND RENTING THE PROPERTY

In the private real estate sector the main conditions that are followed in order to achieve the best outcome of the investment are: the optimization of the profit, obtained by the difference between the financial costs and incomes generated by the project or investment, the reduction of the time frame (as short as possible) and the general assessment that is typically carried out through a cost-benefit analysis. This master's degree thesis focuses mainly on the analysis of an hypothetical investment made by a private, but the consideration are also related to public investments and the restoration plans for the towns, as already anticipated in the paragraph 2.10.

Each investment requires an analysis of the risks linked to it. The main ones are the systematic risk: that is due to changes that may occur in the market (so it is impossible to intervene and reduce it) and the specific risk: this is due to the risk associated with the project (in this case the acquisition and restoration of the pilot building), in this last case it is possible to reduce the risk by increasing the size of the portfolio of investments. Despite being considered something negative for the entrepreneur, the risk of an investment is also the main reason of the remuneration and the potential enrichment of the investor.[22]

The traditional method for the financial evaluation of a private investment are:

- The Payback Period (PBP)
- The Average Yield

The discounting/actualization methods, in which all financial movements generated by the project, which occur at different times, are considered and brought to the same point in time by discounting them at an appropriate discount rate, are based on:

- Net present value (NPV)
- Profitability index (PI)
- Internal rate of return (IRR) [23]

In this master's degree thesis the parameters evaluated are the PBP, the NPV, the IRR and the return on investment ROI.

These indexes provide a general understanding of the potential outcome of the investment. The traditional methods that are based on the PBP, provide an evaluation of the time (in months or years) required to fully recover the initial investment.[24]

- The PBP occurs at the moment when the cumulative cash flow of a project is equal to zero:

$$\sum_{t=1}^{k} \text{Cumulative cashflow} = 0$$

with:

k = number of periods for the recovery of the investment (Pay Back Period)

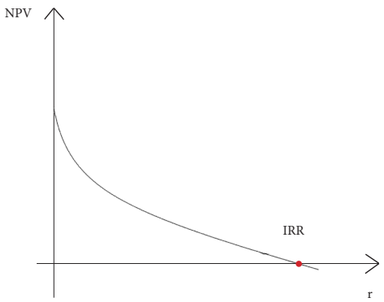
- The NPV (Net Present Value) represents the difference between the present value of cash inflows (revenues) and the present value of cash outflows (costs), obtained by discounting them at a discount rate represented by the risk-free rate of return on the investments or the opportunity cost of capital.
It requires: the estimation of all costs and all revenues, their distribution over time and the choice of the discount rate.

$$NPV = \sum_{t=0}^{N} \frac{C_t}{(1+r)^t}$$

with:

C_t = relevant costs
N= number of the years in the time horizon considered
r= discount rate

- The IRR (Internal Rate of Return) represents the situation in which there is no more convenience in investing other capital. Mathematically it represents the condition in which the curve of the NPV is crossing the x axis (r rate axis) and the NPV=0. In order to obtain IRR it is therefore necessary to solve the previous equation with r as unknown.[25]



Graph 1: NPV curve based on r rate.

- The ROI (Return of the investment) is a percentage that assesses the profit produced by an investment in relation to its expense.
An important elements affecting ROI consist of the initial investment size, continuous maintenance expenses and the cash flow produced by the investment.
The project of conservative restoration of the building, as already anticipated, require a certain investment that is structured in a first expense related to the acquisition of the property and to all the other works that have been accounted before.
For the purpose of this master's thesis, that aims to propose a specific methodology to revitalize fragile towns, the pilot building designed and studied has been considered on sale in the real estate market with a general value of € 20'000, considering the typology, the dimensions and the price of the surrounding buildings already present in the online real estate platforms.
The total cost of the renovation, has been accounted for € 164'030,41 and with the possible extra costs of 15% of the total (€ 24'604,50) the final result is € 188'634,91.
By adding the hypothetical initial price of acquisition of the property, assumed to be on sale for 20'000 € the final cost of the investment will be of € 208.634,91.
There are two scenarios that have been considered: the selling and renting of the property.
- Regarding the acquisition of the property to sell it in the future, based on the data present on the real estate platforms, in August there was an announcement for a property on sale for € 225'000,00 for 381 m^2, with a price for square meter

of 590,55 €/m^2. The same property was present in another website for € 230'000. In the following months the property has been removed from both the real estate websites, this fact suggests two possible scenarios: the property has been sold or the owner decided to not sell it anymore and retired the announcement.
The fact that a property of € 225'000,00 was presented in the market, and followed by another building on sale, but with a lower price of € 130'000, promote the idea that an investment of € 208.634,91 for restoring the pilot building may be a good strategy.
On the other hand, a critical analysis suggests that considering the total number of square meters of the building of exactly 171 m^2 compared to 381 m^2, that are more than the double, there may be certain difficulties to sell the building. It is also important to mention that although advanced technologies and PV panels have been introduced in the pilot building and may lack in the houses of 381 m^2.
The price for square meters, in the case of the pilot building it is equal to:
€ 208.634,91 / 171 m^2 = 1'220,1 €/m^2 that is the price profit margin for the entrepreneur only to cover the costs of the intervention.
Comparing these considerations with the data published online in the most reliable platforms, a more detailed outcome of the analysis emerges.
In fact, although the data from OMI suggest an increase of the price for square meter for the properties in Rosazza, the minimum cost of 1'220,1 €/m^2 for remunerate only the investment is already too high compared to the demand.
The analysis done consider the data collected from the website *ImmobiliaGest* [022] that gather together informations coming from OMI (Osservatorio del Mercato Immobiliare) which is an "instrument" created by the Revenue Agency (Agenzia delle Entrate) that presents a great amount of reliable data about the properties, traidings, values of the assets and many other informations essential to make economical and financial analysis. The dataset formulated by OMI is always updated with the most recent data and It is accessible for free. In the following pictures, the data related to Rosazza have been collected and reported in the tables.
Regarding the price of the houses, the average price in 2025 is € 535,5 and for the terrain it is € 73,5.
The trend from 2015 to 2025 shows a slow increase in the price of the properties without any interruption or decrease during the decade. This provide a first but strong sign of the increase of value of the built heritage of Rosazza, that may continue in the future considering also the increase of chaos in the big cities of Piedmont, the trend of buying single houses in the mountains and the growing number of activities organized in the city.
By adding an extra cost to the price in order to generate profit, it appears clear that the scenario for selling the pilot building restored could be a failed investment.
In fact, considering the total cost of 1'220,1 €/m^2 = 1'220 €/m^2 to remunerate completely the investment, without nay net profit, the price is already high enough.

ImmobiliaGest

ville ricercare

Prezzi immobili Rosazza Valori OMI al metro quadro 2025

Prezzo appartamento	**493.5 € / m²**
Prezzo casa	**535.5 € / m²**
Prezzo terreno	**73.5 € / m²**

Il 2025, il prezzo medio al metro quadro (Valori OMI) a Rosazza in Piemonte è di 525 €. Questo significa che il prezzo è aumentato del 5.79% rispetto all'anno precedente. Rosazza è al 16894 posto nella classifica delle città più costose in italia.

L' OMI Rosazza, Osservatorio del Mercato Immobiliare del comune di Rosazza, costituisce una raccolta pubblica di dati tecnici ed economici, utili alle quotazioni del mercato immobiliare.

Andamento dei prezzi degli immobili a Rosazza

Anno	prezzo per metro quadro
2025	525 €
2024	495 €
2023	467 €
2022	440 €
2021	415 €
2020	391 €
2019	369 €
2018	348 €
2017	328 €
2016	310 €
2015	293 €

Figure 48: Data of the real estate assets in Rosazza. Source OMI and Immobiliagest

Città vicine a Rosazza

Città	Prezzo al metro quadro
Miagliano	525 €
Sagliano Micca	525 €
Sordevolo	492 €
Tollegno	487 €
Pollone	487 €
Campiglia Cervo	525 €
Piedicavallo	525 €
Balma	525 €

Figure 49: Data of the price per square meter of the houses in the closest town to Rosazza. Source OMI and Immobiliagest

- In the scenario of the acquisition and conservative restoration of the property with the aim of renting it as a BeB, the financial analysis changes, considering the flow of incomes spread during the time and the parameters to take into account, such as the tourist flows and the request for temporary accommodations.

The tourist flow has a central impact in the eventual success of the investment. Based on the data collected from OMI, websites and from the interviews conducted to the local residents of Rosazza, the tourism is slowly growing, compared to the previous years. It presents high peaks during the summer, due to the fresh air of the mountain town that provides a relief against the heat of the main cities and It is also encouraged by the increasing number of activities that are organized each year, such as the esoteric tours, hiking, climbing, tennis, bowls game, trekking et cetera.

The pilot building has a total of five floors considering the ground floor, that host the shared kitchen and common space. The BIM model of the building has been produced with a medium-low level of detail LOD, because of the main purposes of the thesis, that are not to develop a detailed and/or executive project, instead to design a typology of intervention according to the urban restriction, that can be tested for applying the PropTech technology and assess the real estate parameters.

The net area of the floors with their functions are:

- ground floor: tot. area= 35 m^2 (Kitchen)
- first floor: 33 m^2 (BeB room)
- second floor: 33 m^2 (BeB room)
- third floor: 33 m^2 (BeB room)
- fourth floor (mansard): 37 m^2 (BeB room)

Total Area= 171 m^2

In the hypotheses of renting with the price of 50 €/night, considering the number of floors that can be rented as a BeB is 4 and the average square meters per BeB is 34 m^2, the redditivity is calculated in the following formula:

150 nights * 50 €/night = 7500 €

Redditivity= 7'500 € / 36'600 €=0,2049 = 20,5%

The result represents a quite high profitability.

Regarding the evaluation and calculation of the before-mentioned financial parameters to assess the potential results of the investment, traditionally the analyses is made with the use of already prepared excel sheets, in which it is possible to edit the main data, such as the size of the building or plot object of the investment, the discount rate, the year of the investment, the initial investment of the entrepreneur et cetera.

All these data input in excel produce a computation in the values of the main parameters and the representation of them through graphs and diagrams. In this thesis the VPL was used to performe the analyses. Starting from a creation of parameters in the model, the information of the building were used.

The main data coming from the project, such as the price per square meter of the room, were evaluated starting from the previous calculations.

After creating the parameters, the financial analyses were performed in order to

understand the potential improvements to do in the project or in the investment.
For assessing the incomes coming from the scenario of renting the apartments, it was necessary to understand the tourist flows in the town and to predict a future scenario, based on the growing number of non resident people accessing the town. The results of the coding computation with virtual programming language, with regards to all the financial parameters, certify that the best scenario for renting the property is the one of using the 4 rooms available for short rents as beb, compared to other scenarios of mixed use with rented offices or only office use. In fact as shown in figure 53, the return of investment in this case is = 16.2%

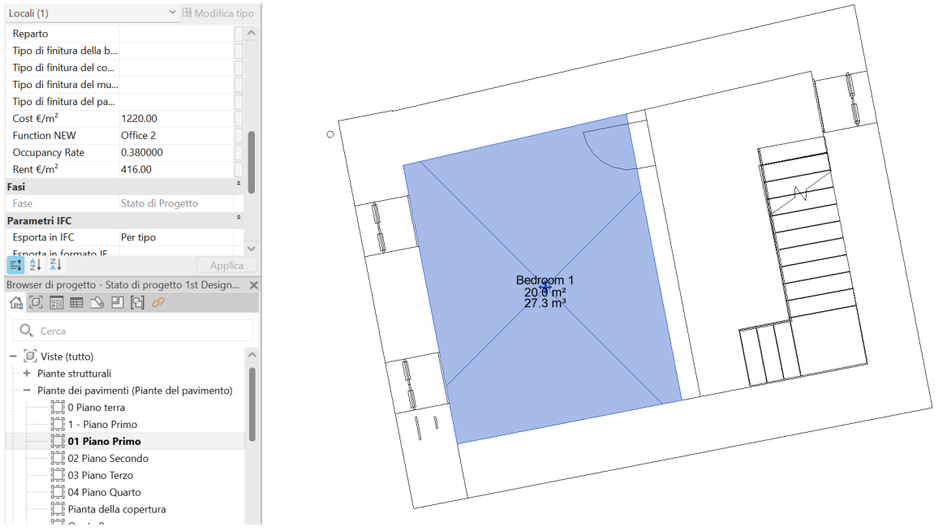


Figure 49: Parametrization of economical properties created inside the BIM model. By Salvatore Tartaglia

Comune	PV	Esercizi Ricettivi	Locazioni Turistiche	Letti in Esercizi Ricettivi	Letti in Locazioni Turistiche	Arrivi Italia
BIELLA	BI	38	167	1.364	531	44.655
VIVERONE	BI	31	20	2.098	93	8.819
SANDIGLIANO	BI	6	2	213	8	10.143
GRAGLIA	BI	6	7	246	27	5.935
CAVAGLIÀ	BI	8	6	161	39	2.181
COSSATO	BI	7	5	68	24	1.483
CANDELO	BI	14	22	68	90	1.703
VALDILANA	BI	17	18	163	117	1.606
ROPPOLO	BI	9	4	82	25	2.031
CAMPIGLIA CERVO	BI	7	9	134	60	1.559
LESSONA	BI	8	3	57	24	714
SORDEVOLO	BI	11	4	108	13	605
MAGNANO	BI	8	6	69	27	1.232
CERRIONE	BI	7	2	61	8	574
POLLONE	BI	6	6	83	23	438
MUZZANO	BI	8	2	274	9	640
PETTINENGO	BI	7	3	92	14	342
BIOGLIO	BI	5	3	48	14	-
GAGLIANICO	BI	5	6	37	19	-
ZUBIENA	BI	5	2	31	12	-
DONATO	BI	4	4	76	13	-
NETRO	BI	4	7	21	28	-
PIEDICAVALLO	BI	4	0	50	0	-
ROSAZZA	BI	4	2	40	8	-

Figure 50: Data on tourist movements from: Tourist movements of customers in accommodation establishments. Municipal data - Year 2024
Source: Osservatorio turistico della regione Piemonte

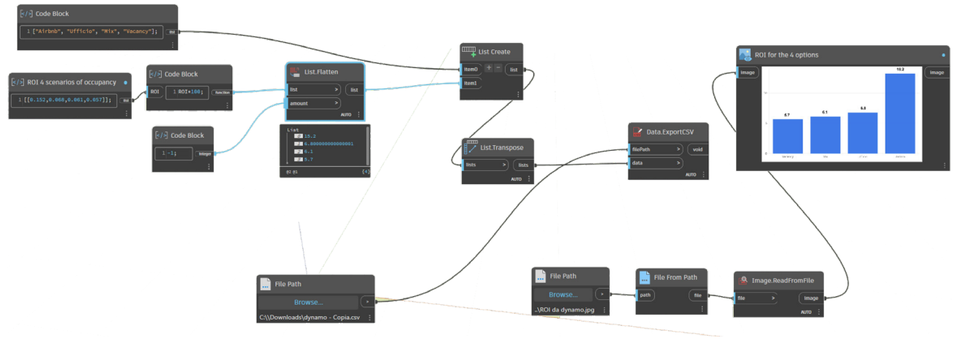


Figure 51: VPL script with the simulation of different hypotesis for the renting scenario and calculation of ROI . By Salvatore Tartaglia

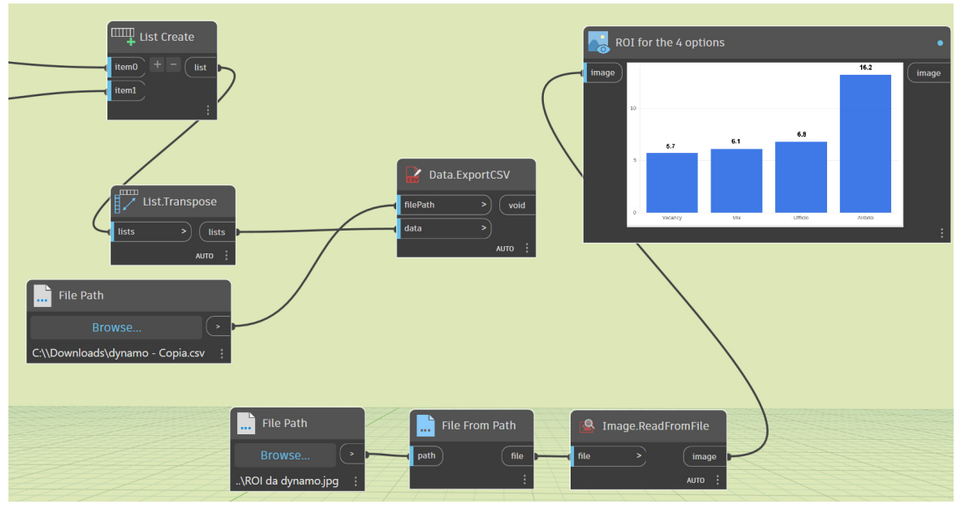


Figure 52: Zoom/in of the script . By Salvatore Tartaglia

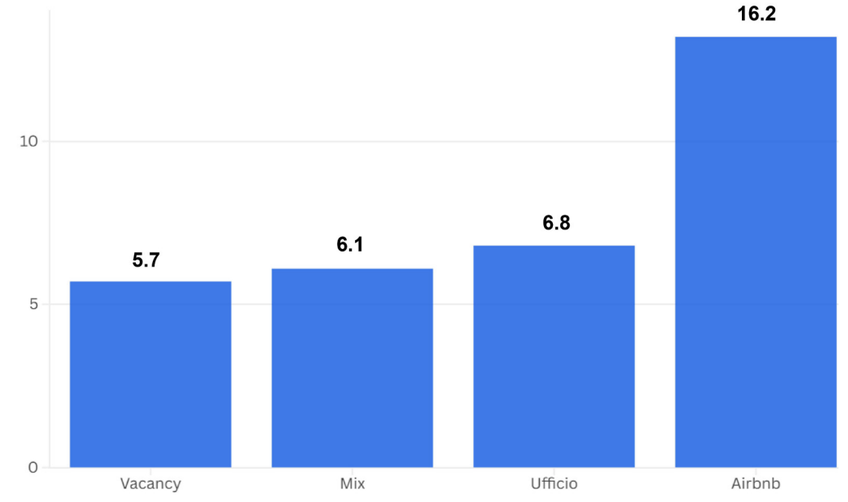
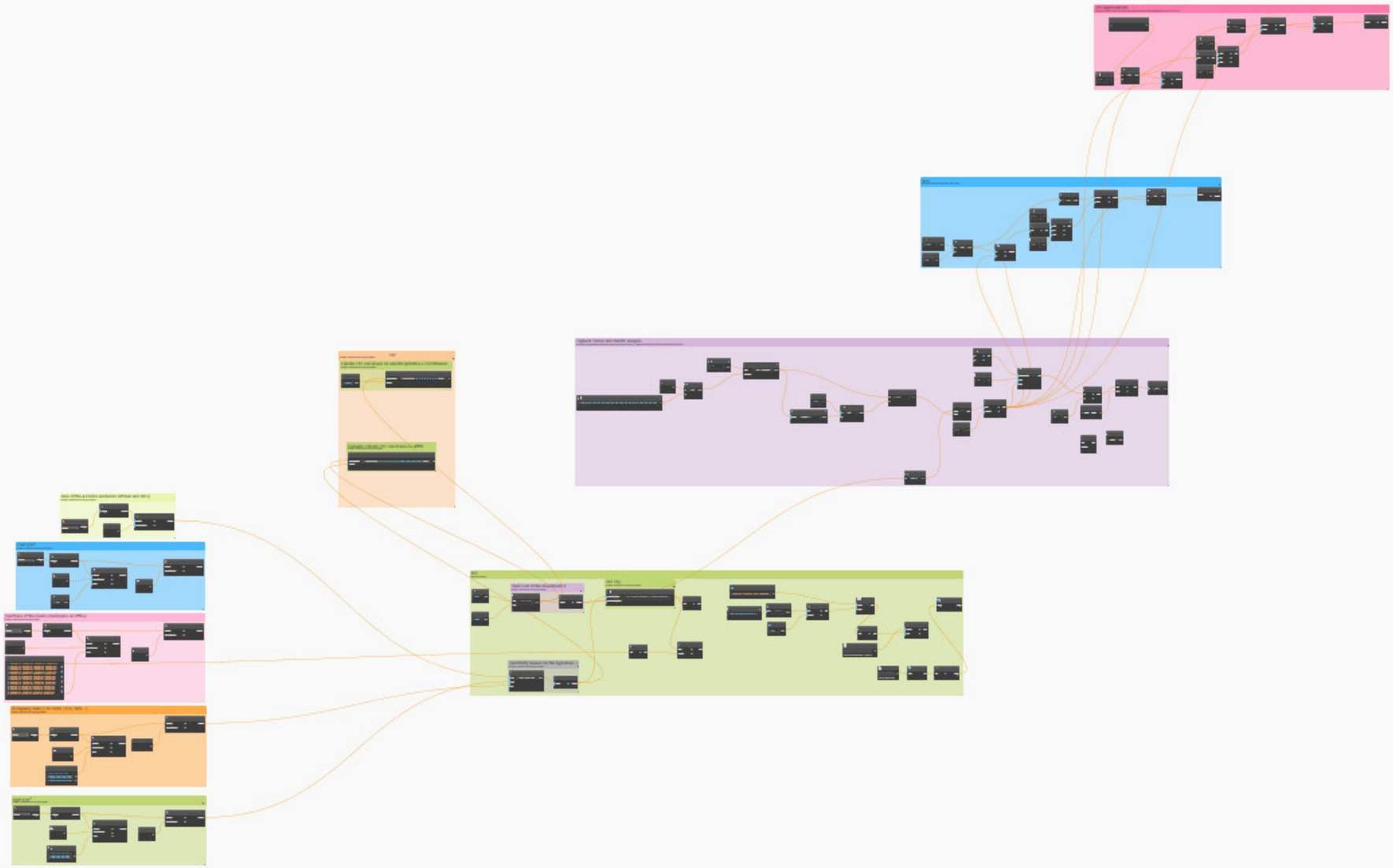


Figure 53: Final results of ROI for the different scenarios in the case of Vacancy, Mixed use, Office or all BeB . By Salvatore Tartaglia



Full script of the financial analysis. By Salvatore Tartaglia

RENDERS OF THE PROJECT:

Render of the conservative restoration of the building. By Salvatore Tartaglia

Render of the toilet on the 4th floor. By Salvatore Tartaglia

Render of the bedroom on the 2nd floor. By Salvatore Tartaglia

Figure 54: The guardian of the park. By Salvatore Tartaglia

"Sono onda che disseto, rammentando, il mio autore". Fountain of the column with inscription. By Salvatore Tartaglia

Figure 56: Cat in the stairs of via Moro Mosca. By Salvatore Tartaglia

Figure 57: Gnomes looking out of the windows. By Salvatore Tartaglia

CONCLUSIONS AND FUTURE DEVELOPMENTS

4

The central goal of this thesis in architecture for sustainability was to determine the effect of the integration of BIM, GIS, and IFC interoperability in the optimisation of sustainable architecture and private real estate efficiency.

Specifically, through the use of interoperable digital models, the research aimed to automate and optimise data extraction, cost estimation, and economic-financial simulations within the real estate investment process. This dataset supports external analyses, positioning the entire workflow within the framework of digital innovation for sustainable design and construction.

The integration with GIS allowed the inclusion of territorial and topographical data, creating a unified model focused on economic sustainability while maintaining balance with environmental and social aspects. These three pillars form the foundation of sustainability and guide the development of resilient and responsible architectural strategies.

A key contribution of this research is its alignment with the principles of Whole Building Design, promoting a holistic and integrated approach to sustainability. By situating design within a shared digital environment, the thesis contributes to the ongoing effort to improve the precision, coordination, and consistency of solutions addressing the complex challenges of contemporary architectural and urban regeneration.

The application to the fragile mountain town of Rosazza, where a BIM-based architectural project for conservative restoration was developed and integrated with cost estimation and real estate financial analysis, validated the method's transferability and demonstrated the potential of building digitisation as a strategic tool for planning enhancement, restoration, and reactivation initiatives in historic mountain contexts.

The generation of an urban BIM model interoperable with GIS marks a first step toward developing Digital Twins and smart territorial systems, capable of connecting technical, economic, and environmental data to simulate sustainable usage or investment scenarios.

By combining technical-performance analyses with economic feasibility, the proposed method supports design decisions that respect heritage protection while stimulating local regeneration through tourism, social cohesion, and re-population of abandoned villages. This scalable and interdisciplinary approach provides a foundation for a digital transition in sustainable design and territorial management.

Future work will focus on creating a territorial Digital Twin and advancing economic-financial evaluation tools within BIM, in line with the PropTech perspective, to support more accurate, dynamic, and integrated decision-making for sustainable urban and architectural regeneration.

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