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FragMONT

Integrated System for the Management of Fragility in the Mountains

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Foreword

FragMont was born from ideas matured along a path of mountain research activities, traced by researchers with a Commodity Science background, and from meetings with other researchers equally interested in mountain-related topics. Work carried out over 25 years in different contexts, but all unified by certain common points: the mountain as a unique place for experimentation, interactions with residents and tourists, the variety of researchers with complementary professional skills, met on-site or at national and international conferences, the desire to understand and contribute to overcome the difficulties of areas too often considered, and, indeed, treated as marginal.

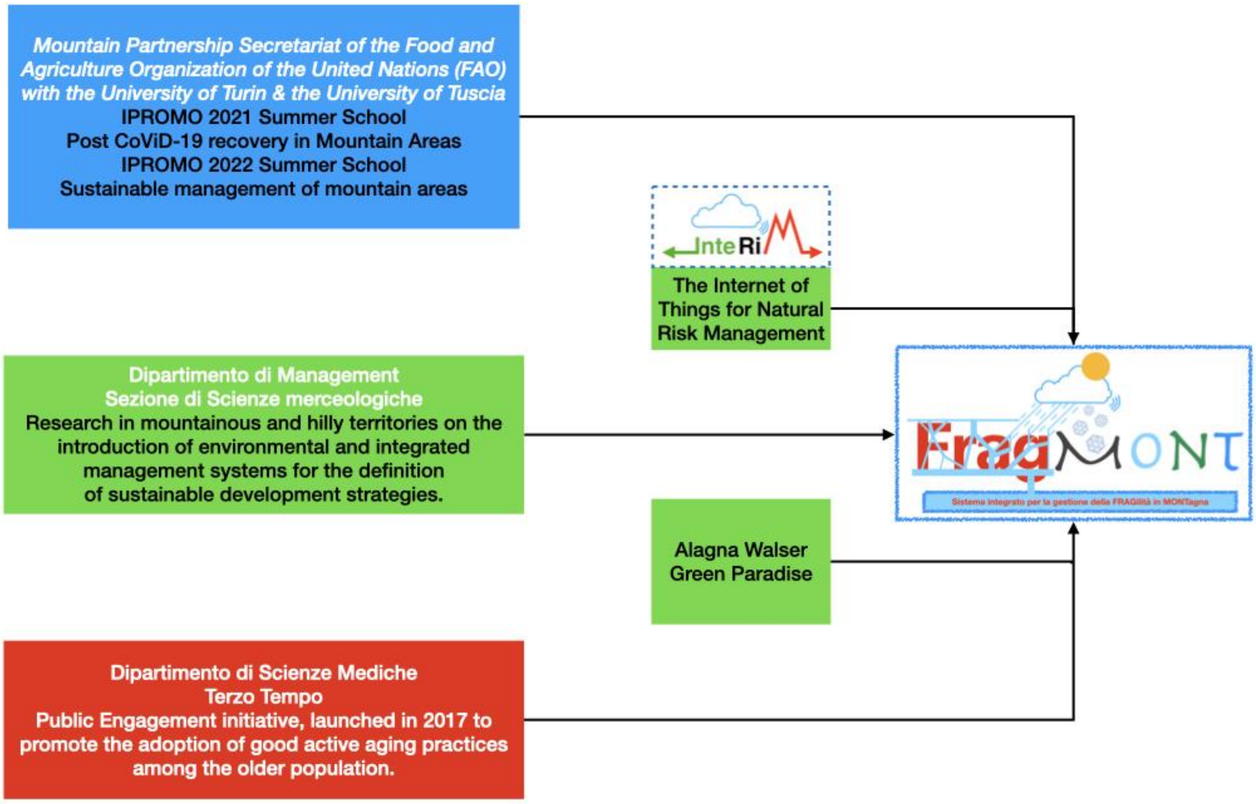


Figure 1: Fragmont project participants

In the Commodity Science Section of the Department of Management, we have always operated by focusing on the fragility of the mountain. We have addressed environmental fragility, influenced by the interactions between economic organizations and the environment, identifying research paths that would lead to management solutions capable of reconciling the hosting of tourists with the environmental impacts generated by their presence and permanence in fragile ecosystems. By improving management for better environmental qualification of economic organizations, the involvement of human resources and the definition of training paths have been directed. The solutions, translated into guidelines over time, have made possible the networking among local operators, and so the diffusion of mountain-related knowledge to highlight and propose possible sustainable tourism solutions.

The research carried out has also been influenced by the work conducted within the Interdepartmental Center on Natural Risks in Mountainous and Hilly Environments - NatRisk and has taken into consideration the insights arising from the dialogue with CIPRA Italia and UNCEM, authoritative bodies working on mountain and inner area issues, whose in-depth analysis and dissemination are essential to foster and increase awareness of the need for sustainability policies.

The evolution made through the study of the Internet of Things has opened new

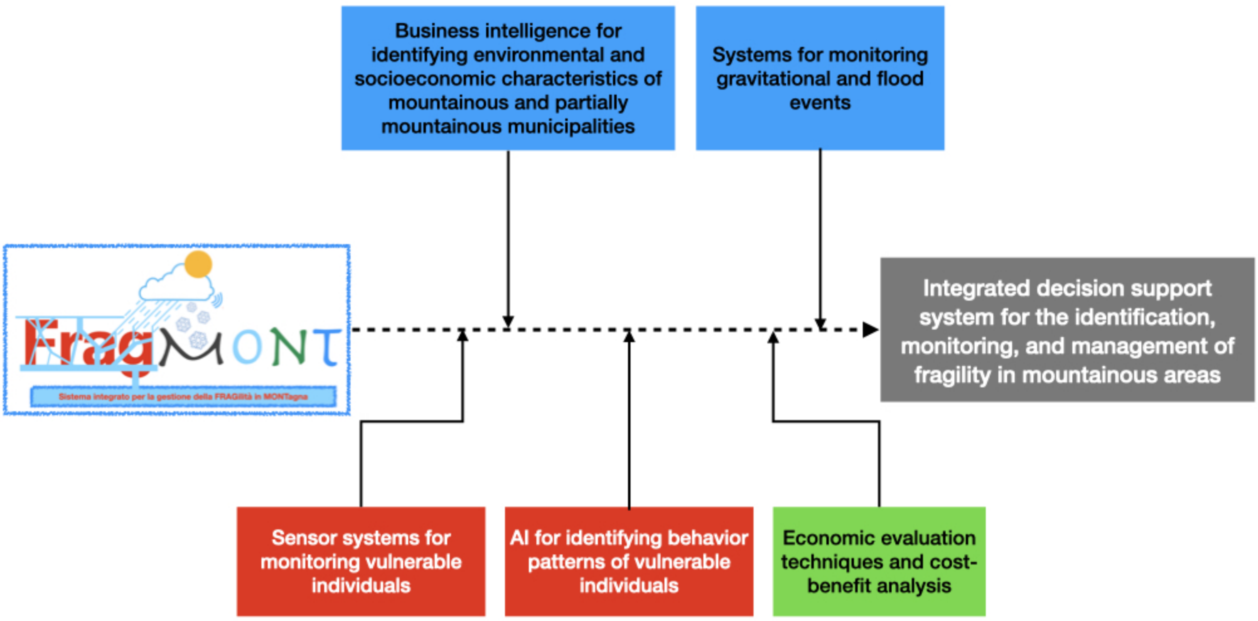


Figure 2: Fragmont overall workflow

opportunities for us, in terms of research, thanks to the development and implementation of networks capable of detecting parameters for the formulation of environmental sustainability indicators, and, in terms of dissemination, thanks to the possibilities of data representation and sharing. The activities developed within the Inte.Ri.M. Project, Internet of Things for Natural Risk Management, self-financed by the Department of Management, consisted in experimentation with sensors and techniques for monitoring hydrogeological instability. These activities accelerated following the meeting with CNR-IRPI, within the framework of various editions of the Ipromo Summer School, promoted by the Mountain Partnership Secretariat of the FAO (Food and Agriculture Organization of the United Nations) together with the University of Turin and the University of Tuscia. Insights derived from CNR-IRPI's theoretical and field research have enriched FragMont through a journey of collaborative knowledge-sharing and strategic planning.

Our participation in 2017 in the call for #hackUniTO for Ageing, an initiative launched by the University of Turin to promote research related to ageing among all universities, and national research bodies, created the conditions for a dialogue with the Department of Medical Sciences of our University. Of particular importance was the participation in the Public Engagement initiative "Third Time", aimed at fostering the adoption of good practices of active ageing among the older population. The insights acquired have evolved into one of the key research avenues within FragMont.

In the initial phase of defining the project and its activities, or to formulate the proposal presented to the CRT Foundation, FragMont has thus benefited from the ideas and contributions of the territorial, health, and economic areas.

The project was designed to identify, understand, and tackle fragilities complementary to those considered within the projects of the Commodity Science Section, i.e. hydrogeological instability and related issues, or those arising from the presence of fragile people in the mountains and their needs. It represents a new stage, achieved through collaboration with researchers specialized in their respective scientific fields, and oriented towards systemically connecting their skills to reach an innovative and useful result.

The underpinning framework that facilitated the planning and execution of the project was an integrated management systems approach. This served as the foundation for a decision support system, elaborated in this report, which was specifically designed to aid public administration. Along the way, researchers carried out several activities (i.e. design or experimentations) which involved the utilization of hardware and software systems, and benefited from the application of both traditional and innovative techniques (such as, business intelligence and artificial intelligence tools). In addition to the specific contribution or the variety of methodologies and know-how, dialogue and field applications were crucial to increase the sensitivity of the research group members towards different areas of knowledge, as well as their awareness regarding the importance of providing holistic contributions to tackle real problems. In our journey, we have benefited from the financial support of the CRT Foundation, which has allowed us to finance research grants dedicated to the project; we also had useful discussions with UNCEM and CIPRA ITALIA, organizations to which we are grateful and that represent important references. We hope that what will emerge from this report will be useful for the identification of policies aiming at generating or fostering mountains development, enhancing, and preserving their distinctive characteristics.

The activities and results of FragMont are related to sustainable development and have a direct relationship with the following goals included in the United Nations' 2030 agenda:

- Goal 3: Ensure healthy lives and promote well-being for all at all ages.
- Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.
- Goal 11: Make cities and human settlements inclusive, safe, resilient, and sustainable.
- Goal 13: Take urgent action to combat climate change and its impacts. Goal 15: Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, halt and reverse land degradation, and halt biodiversity loss.

Figure 3: SDG's involved within the fragmont project

This document constitutes the English translation of the final project report, available in the Italian version at https://www.collane.unito.it/oa/items/show/137#?c=0&m=0&s=0&cv=0. Additionally, some paragraphs have been expanded with new contents discovered by the researchers through the use of the AI tool ChatGpt and with images created with Microsoft Bing. The authors are grateful to Dr. Giulia Lippi, research fellow at the Department of Management of the University of Turin, for her meticulous work in proofreading and editing the text.


Figure 4: Data visualization of a Network management system for natural and sanitary risks. Image automatically generated by Bing AI

Introduction

The FragMont Project - Integrated System for the management of FRAGility in the MOUNTain - was presented to the CRT Foundation by the Commodity Science research group of the Department of Management of the University of Turin. Researchers from the Department of Medical Sciences, the CNR-IRPI - Research Institute for Hydrogeological Protection, and the Interdepartmental Centre NatRisk - Research Centre on Natural Risks in Mountain and Hill Environment also participate in the initiative. The project was developed in collaboration with national bodies (CIPRA ITALY - UNCEM), regional bodies (Piedmont Region and ARPA), and the municipalities of Alagna Valsesia (VC) and Moncucco Torinese (AT). FragMont seeks to compare the costs of preventive measures with the potential financial losses from natural disasters that could affect essential ecosystem services. The project takes into consideration a variety of contributing factors, multiple kinds of vulnerabilities, and challenges like the potential isolation of at-risk individuals. The distance between peripheral mountain areas and hospital facilities exacerbates this fragility, leading to critical conditions for the healthcare for fragile population, identifiable with the condition of the elderly and all people affected by chronic diseases in need of care, whose numbers are increasing, also due to the CoViD-19 emergency.

The goal of the project was pursued through the study of natural disaster risks (landslides, floods, avalanches etc.) based on bibliographic analysis and the study of monitoring data, including those made available by the Piedmont Region Civil Protection Service, the Piedmont Regional Agency for Environmental Protection (ARPA), and the CNR - IRPI.

The main expected result is the development of a management system aimed at tackling the fragility of mountain territories, supporting the preventive organization, coordination and evaluation of restoration works, going through healthcare, with cost estimates and, therefore, the possible benefits derived from reducing the risk itself. The need for a system of this kind has emerged not only from the analysis of the literature and recent news events, but, more directly, from the dialogue of our research group with some realities of the territory, particularly with the Piedmont Region - Civil Protection, ARPA, and some mountain municipalities, among which that of Alagna Valsesia, already engaged in projects to qualify sustainable tourism offer.

FragMont has developed guidelines applicable to municipalities where isolation situations may occur (similar in characteristics to those identified as representative of the most frequent situations), referring to situations detected in the municipalities participating in the Project and evaluating the functionality and actual costs sustained for prevention and the economic benefit achieved.

In addition to Piedmont, other regions with similar territorial and morphological characteristics could benefit from the results of the Project: these are regions characterized by the presence of mountain territories where tourism activities have a great economic significance, and areas sparsely populated mostly inhabited by an elderly population. The Project focused on evaluating actions to prevent disasters in the mountain area and those related to the isolation of people, especially the most fragile ones. Often, indeed, the total costs of losses and restoration resulting from disasters are not correctly evaluated nor compared with the real costs of prevention. For this reason, a sense of urgency is emerging, as testified by measures at various institutional levels that motivate studies for the implementation of a system developed with new technologies and integrated with economic evaluations.

To respond to these needs, expressed primarily by the regions of the Alpine arc and the Apennine ridge, as documented by the studies of CIPRA and UNCEM, it is essential to highlight the economic sustainability of the actions to be implemented; and this can be done through the analysis of the sustained costs for monitoring and prevention, compared to those avoided (mitigation, preparation, and emergency response). This approach, which includes evaluations of ecosystem services, can be useful in providing information to estimate costs and benefits of different decisions, define future scenarios, recognize, and avoid unexpected consequences.

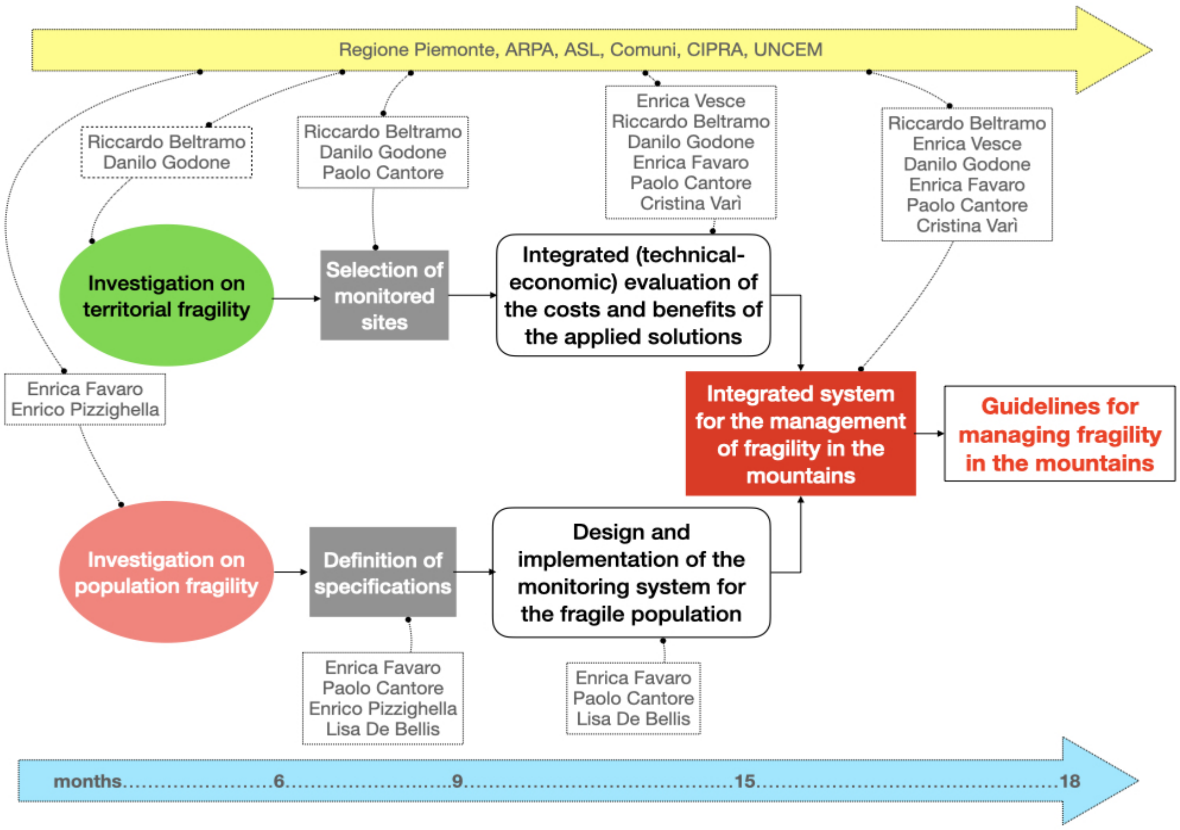


Figure 5: Flow diagram of the FragMont Project

The first six months of activity were dedicated to conducting an in-depth analysis of environmental and population fragility. These were two parallel lines of research, both engaging two different work groups, one related to management and environment fields, while the other focus on the health dimension. The purpose of this phase was to evaluate, using data provided by third parties such as the Piedmont Region, ARPA and Municipalities, the actions to be implemented for the environmental monitoring and protection; for example, landslide nets, avalanche breaking systems, and landslide ground sensors. The identified risk scenarios were also the basis for the economic evaluation of preventive interventions and, if any, of the restoration works in case of the occurrences of site-specific hazards that might be generated.

At the same time, practical modalities, to be included in the guidelines, were evaluated to estimate potentially isolated people and the costs of providing them with assistance. During the second phase, sites, located within the participating municipalities, monitorable by sensors or equipped with preventive works, were analyzed. For these sites, attempts were made to identify and quantify the economic costs for monitoring, the works already carried out (for example by ARPA, the Region, or Civil Protection), and the overall stakeholders.

A similar analysis was conducted in parallel to define the characteristics of the telemedicine system, useful for the considered population. The prototype was structured to remotely measure and send some biometric parameters, such as oxygen quantity, blood pressure, heart rate, and blood glucose level. In addition to the telemedicine prototype, a network for monitoring the environment in which the elderly person lives was created. The system was set up and tested in a real case of an elderly person’s home, allowing the observation of several parameters as well as the possibility to provide useful indications on safety and health status of the targeted person.

At the same time, the economic evaluation of both the benefits provided by the assistance system, and of the works put in place to prevent environmental damage, was set up. In this latter case, not only the costs of the avoided emergency interventions were considered, but also the impacts of the averted damage on economic activities that would have been affected by the environmental event.

This assessment was strengthened by an analysis of the ecosystem services present in the area of interest, so that the estimate of costs and benefits would be as exhaustive and complete as possible, from the perspective of territory preservation. For instance, once having detected the danger of an avalanche, the intent would be to control its effects, preventing the interruption of the only access road to a ski resort, that would otherwise have to suspend its activity, losing revenues. At the same time, from a qualitative point of view, the ecosystem services analysis allows to consider the intrinsic value of the local natural resources threatened by the occurrence of the event in question. This approach provides the policymakers with a broad overview of the magnitude of the event under examination, with each aspect being weighted and exhaustively analyzed.

1. Territorial fragility and population fragility

The ultimate goal of the FragMont Project consists in the identification of a set of tools to counter situations of fragility, which is conceived as a condition of vulnerability, namely the exposure to real risks that concretely threaten the maintenance of life in mountain and hill territories. Researchers have been working for years in such domains, which, together with their long-standing attendance of the territories, has led to the identification of the research questions. For this reason, the two macro-areas on which the investigation focuses are territorial fragility and population fragility.

In Italy, 43.7% of municipalities are localized in mountainous areas, and, of these, 49.2% are in Piedmont. It is now evident that the threat of natural disasters in these territories has increased in frequency and intensity, while the recent news events only confirm this alarming trend.

“Italy is the European country most affected by landslides, with 2/3 of the landslides recorded in Europe (EuroGeoSurveys Survey 2015). Landslides are extremely widespread due to the geological and morphological characteristics of the Italian territory, which is 75% mountainous-hilly.”[1]

Regione / Provincia autonoma	Area Regione/ Provincia Autonoma (1)	Numero di frane (2)	Numero di eventi franosi principali 2020	Densità delle frane	Area interessata da frane	Indice di Franosità (3)	Indice di Franosità su territorio montano-collinare
	km²	*n.*	*n.*	*n./100 km²*	*km²*	*%*	*%*
Piemonte	25.387	36.781	12	145	2.410	9,5	12,8
Valle d`Aosta	3.261	5.812	3	178	607	18,6	18,6
Lombardia	23.863	142.007	25	595	3.880	16,3	34,2
Bolzano-Bozen (4)	7.398	10.978	1	148	806	10,9	11,1
Trento	6.207	9.397	11	151	888	14,3	14,6
Veneto	18.345	9.445	16	51	232	1,3	3,2
Friuli Venezia Giulia	7.932	5.822	2	73	526	6,6	11,7
Liguria	5.416	13.475	8	249	536	9,9	10,1
Emilia Romagna	22.445	79.893	1	356	2.738	12,2	24,4
Toscana	22.987	115.625	7	503	2.541	11,1	13,1
Umbria	8.464	34.573	3	408	654	7,7	8,7
Marche	9.401	39.833	5	424	1.723	18,3	19,9
Lazio	17.232	10.548	6	61	400	2,3	2,9
Abruzzo	10.831	8.493	4	78	1.242	11,5	11,9
Molise	4.460	23.940	1	537	623	14,0	14,8
Campania	13.671	23.439	7	171	977	7,1	8,8
Puglia	19.541	843	0	4	84	0,4	1,0
Basilicata	10.073	17.673	0	175	774	7,7	8,2
Calabria (5)	15.222	10.100	3	66	885	5,8	6,4
Sicilia	25.833	24.401	3	94	1.238	4,8	5,5
Sardegna	24.099	1.523	4	6	186	0,8	0,9
ITALIA	**302.068**	**624.601**	**122**	**207**	**23.950**	**7,9**	**10,6**

Figure 6: Overview of Landslides in italian region
Source: https://annuario.isprambiente.it/sys_ind/report/html/737

[1] https://it.wikipedia.org/wiki/Alluvioni_e_inondazioni_in_Italia

This translates into a real threat not only to the preservation of biodiversity, a non-negligible element in a world that is significantly deteriorating, but also to the safety of people living in these places or who decide to spend their holiday there. Climate change, improper use of resources, and carelessness of territories are the factors that most affect the already very fragile natural balances.

The natural effects of these phenomena, such as the alteration of the quality of the environment and of the overall territory, are coupled with substantial economic losses, especially due to their social, health, and cultural impacts, both in the short and long run, which significantly compromise the economy of the mountain system.

The inevitable effect of this vulnerability is represented by the constant and relentless abandonment of mountain areas by young people, which consequently causes an ageing of the resident population. The demographic profiles of mountain municipalities confirm a systematically greater presence of the elderly than in urban areas [2]. If we also consider the national situation in the pre-pandemic era when, according to Eurostat, the average life expectancy at birth in Italy was 82 years, this picture can only worsen the situation of instability affecting inland areas.

At the same time, a growing trend concerns the manifestation of chronic diseases, which affect almost 40% of the Italian population. This means that chronic patients in 2028 will be 25 million, while multi-chronic patients will reach 14 million. In addition to the aging of the population, therefore, the problem of chronicity represents a very important challenge which must be properly managed at all levels, requiring additional health, economic, and social resources.

Given these premises, it is believed that the demographic disproportion of mountain and hill areas brings with it the intensification of fragility among the population, exacerbating also by the distance between those municipalities and hospital facilities. The immediate consequence of this uncomfortable situation, especially for the elderly and for the people most in need of care and assistance, is represented by the displacement towards larger centers properly equipped with socio-health facilities, thus generating further abandonment of the internal areas.

For this reason, the ultimate aim of the FragMont Project is to economically evaluate the implementation of preventive interventions and/or consequences of environmental or health risk situations, thoroughly analyzing, on one hand, the incurred and/or avoided costs and, on the other hand, the revenues derived, for example, from a greater tourist and settlement influx towards locations equipped with telemedicine services or systems supporting the securing of the territory. This type of analysis will therefore allow the identification of

[2] https://www.alpconv.org/fileadmin/user_upload/Publications/RSA/RSA5_EN.pdf

scenarios useful for the processes of planning and managing the territory according to the protection objectives considered as priorities.

2. Mountain and marginal municipalities, characteristics

One line of research focused on quantifying mountain municipalities, or those most at risk of isolation because they exhibit certain characteristics.

To identify which municipalities are mountainous, it is possible to refer to the list available on the Informative Mountain System (Ministry of Agricultural, Food and Forestry Policies, 2010), which relies on Istat data and distinguishes three categories of Italian municipalities: "totally mountainous", "partially mountainous", and "non-mountainous", as defined by the art. 1 of law 991/1952 (Chamber of Deputies, 1952).

A municipality can be identified as "totally mountainous" or "partially mountainous" if the difference in altitude between the lower and upper levels of its territory is not less than 600 meters. Moreover, a "totally mountainous" municipality must have at least 80% of its area above 600 meters ASL.

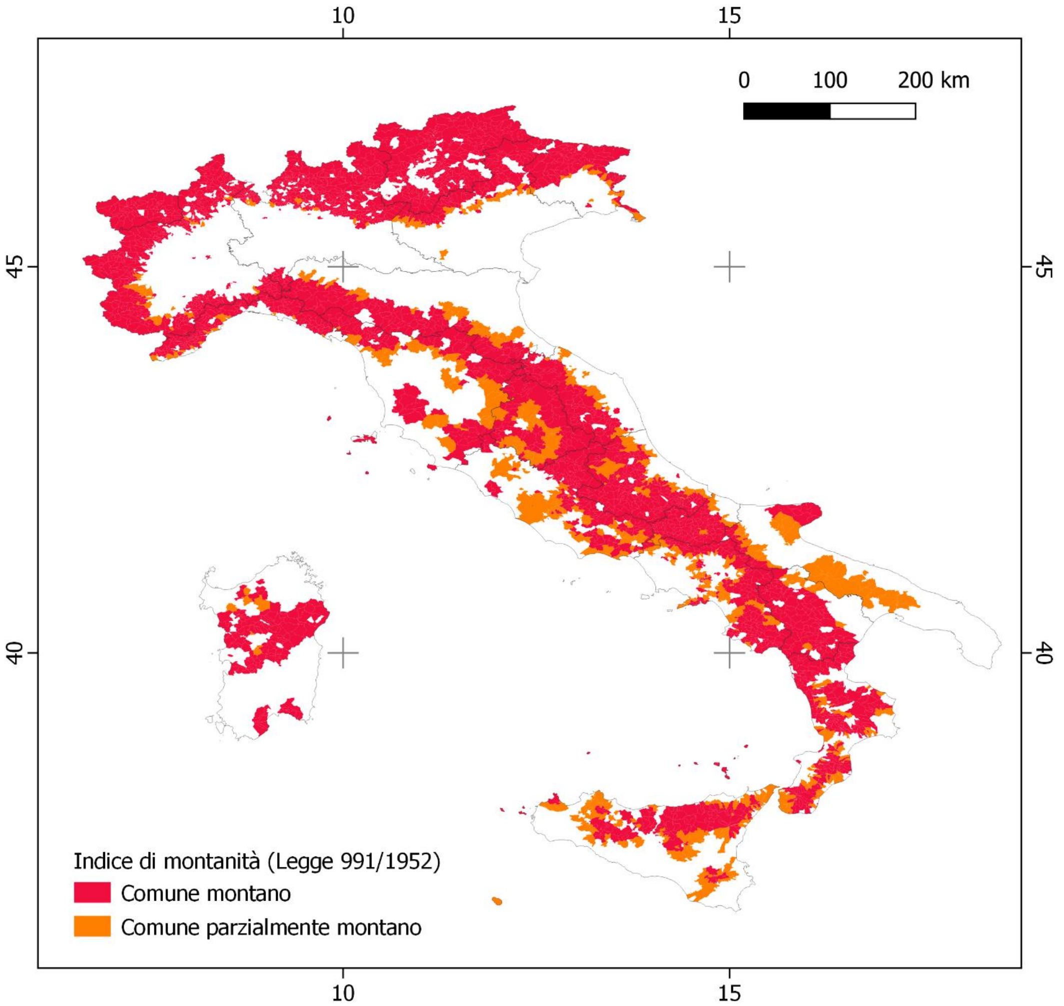


Figure 7: Location of Italian mountain and partially mountain municipalities

Another criterion used to identify and analyze areas of project interest consisted in the selection of municipalities defined as "marginal or disadvantaged"; namely those simultaneously subjected to the risk of depopulation, suffering from social deprivation, and with a population income below the first quartile of the overall distribution of municipalities (Department for Cohesion Policies, 2020). This concept helps to understand vulnerability from the perspective of the elderly population, and the resources available for use in social and service activities.

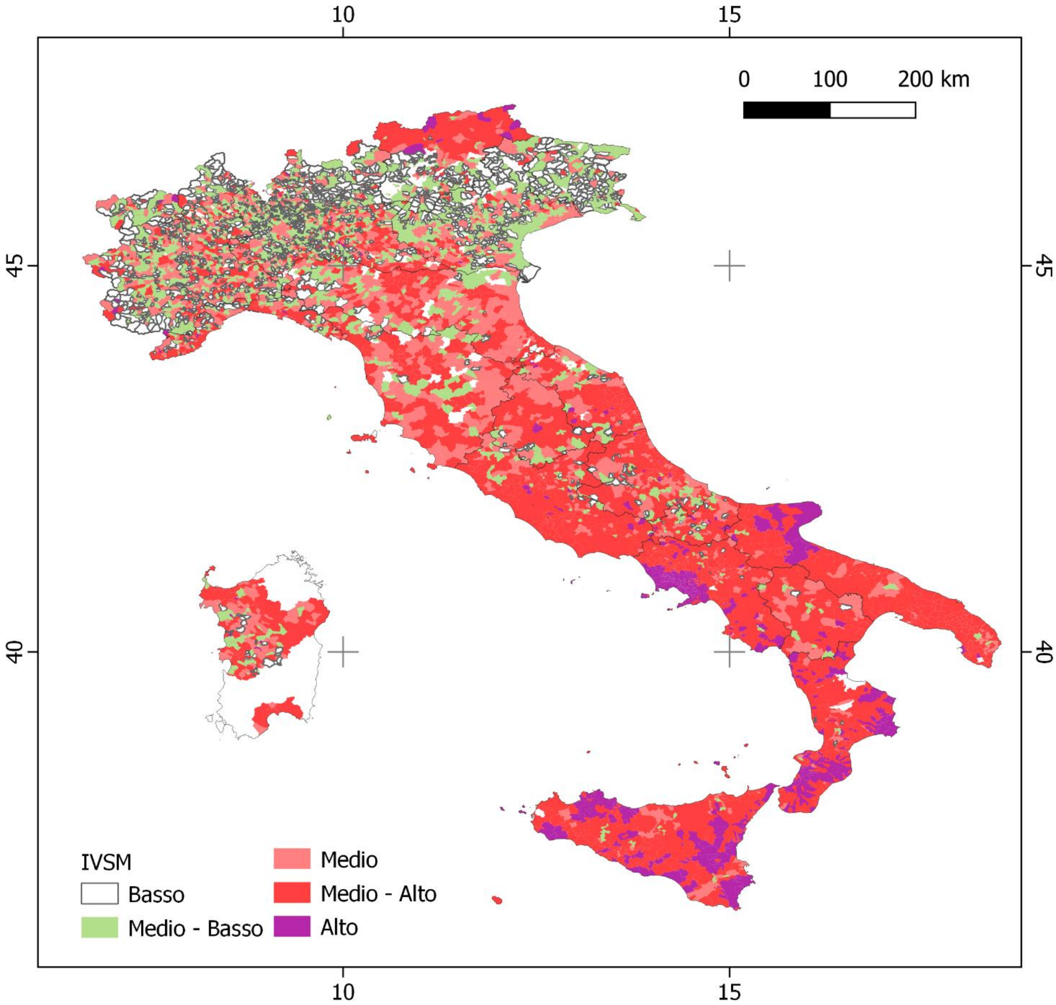


Figure 8: Location of marginal municipalities on Italian territory

The two classification criteria led to the construction of two divided database, which later have been processed to create a unique one. The final database collects and cross-references a series of ISTAT (Italian National Institute of Statistics, 2017) information, defining the socio-economic context (such as population distribution by age, income, education, employment, etc.) for each Italian municipality previously identified.

Given the mountainous context in which the research operates and the Project's objectives, data were gathered at a higher level of detail than with respect to the single municipality, relying on ISTAT data divided by locality, i.e., distinguishing the information related to two different hamlets within the same municipalities. This kind of information granularity is useful to assess precise cost-benefit calculations, as well as to the identification of priorities in the public agenda.

On the one hand, there was a list with low cardinality (4,193 mountain or partially mountain municipalities and 7,904 disadvantaged municipalities); on the other hand, there was a table with over 65,047 localities each with 150 fields, including, for example, data on the population like the division by gender and age, the level of schooling, or the number of families, as well as geographical data, such as altitude, and cadastral data such as the age of the buildings constructed or their state of preservation.

In addition to the massive amount of data to be cross-referenced, one of the main problems encountered in this stage of the research was the lack of an exact correspondence: for example, a postal code, or another key field, which is unique and identified for all municipalities. For instance, the list of marginal municipalities had only the fields "Region" and "Municipality Name" as information to identify a municipality, while the list of mountain municipalities had only the name and the province. Furthermore, since the three data sources were created in different years, many municipalities have changed their name or are no longer part of the same province they were before the change.

To overcome these difficulties, it was decided to process the data using Microsoft's Power BI Business Intelligence application (Microsoft, 2014). This software allows to import data from different sources (i.e., PDF documents, HTML pages, databases, and Excel spreadsheets), and to set rules to be applied to fields in order to perform the union between different tables, like those utilized to perform a JOIN operation on a database.

For example, it is possible to combine the records of a city called 'unoDueTrè' in one database with other data present in another source as 'unoDueTré', also setting the rule that the association is made only if the "Province" field is the same in both tables. Similarly, it is possible to set a rule that converts the abbreviation of the old province of Forlì-Cesena FO into the new FC, or that a municipality belonging to the province of Milan is correctly associated with one present in another list with the same name, but under the province of Monza Brianza.

To speed up the execution of the algorithm, it was decided to run it in several stages. Firstly, the special cases of municipalities that have changed region have been treated, resulting in being inserted in different regions depending on the reference year of the source table. Later, the algorithm was run on sections of the tables divided by regions, aggregating the data only at the end of the process.

The culminating output is a comprehensive report that categorizes municipalities as mountainous, partially mountainous, or marginal. This document offers a detailed breakdown of their attributes, as captured by ISTAT censuses, segmented by locality.

In particular, the data considered is visible in Table 1:

Tematica	Campo
Location identification data	Istat identification codes by region, province and municipality
	Municipality name
	Hamlet name
	Province name
	Region name
	Numeric code identifying the type of locality. The field can be filled with the following values: 1. town area 2. built-up area 3. production site 4. scattered houses
	Numeric codes identifying demographic size of the locality. The code can take the following values, depending on the number of inhabitants: 1. 1.000.000 or more inhabitants 2. 500.000 - 999.999 inhabitants 3. 200.000 - 499.999 inhabitants 4. 100.000 - 199.999 inhabitants 5. 50.000 - 99.999 inhabitants 6. 20.000 - 49.999 inhabitants 7. 10.000 - 19.999 inhabitants 8. 5.000 - 9.999 inhabitants 9. 2.000 - 4.999 inhabitants 10. 1.000 - 1.999 inhabitants 11. 500 - 999 inhabitants 12. 200 - 499 inhabitants 13. inhabitants < 200
	Numeric code set to 1 in the case of regional capital or 0 otherwise.
	Altitude of the location
Resident population	Total
	Male
	Female
	Unmerried
	Married (+ de facto separated)
	Legally separated
	Widow/er
	Divorced
	Unmarried males
	Married or de facto separated males
	Legally separated males
	Widowers males
	Divorced males
	Age < 5 years
	Age 5 - 9 years
	Age 10 - 14 years
	Age 15 - 19 years
	Age 20 - 24 years
	Age 25 - 29 years
	Age 30 - 34 years
	Age 35 - 39 years
	Age 40 - 44 years
	Age 45 - 49 years
	Age 50 - 54 years
	Age 55 - 59 years
	Age 60 - 64 years
	Age 65 - 69 years
	Age 70 - 74 years
	Age > 74 years
	Males - Age < 5 years
	Males - Age 5 - 9 years
	Males - Age 10 - 14 years
	Males - Age 15 - 19 years

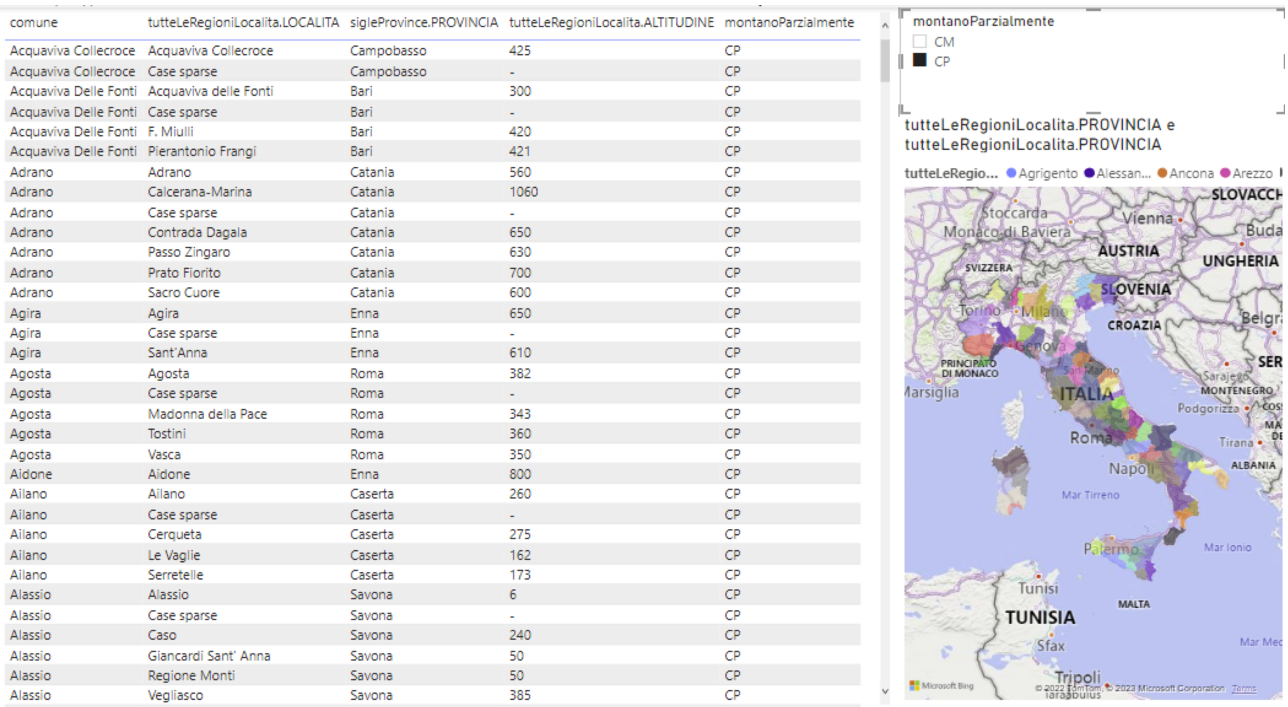
	Males - Age 20 - 24 years
	Males - Age 25 - 29 years
	Males - Age 30 - 34 years
	Males - Age 35 - 39 years
	Males - Age 40 - 44 years
	Males - Age 45 - 49 years
	Males - Age 50 - 54 years
	Males - Age 55 - 59 years
	Males - Age 60 - 64 years
	Males - Age 65 - 69 years
	Males - Age 70 - 74 years
	Males - Age > 74 years
	Total population older than 6 years old
	Resident population with new or old university degree + other university diplomas + non-university tertiary diplomas.
	Resident population with high school diploma
	Resident population with middle school diploma
	Resident population with elementary school diploma
	Literates
	Illiterates
	Males older than 6 years old
	Males with new or old university degree + other university diplomas + non-university tertiary diplomas.
	Males with high school diploma
	Males with middle school diploma
	Males with elementary school diploma
	Literates males
	Illiterates males
	Total population older than 15 yo belonging to the total workforce
	Total employed population (older than 15 yo)
	Total unemployed population (older than 15 yo) seeking for new employment
	Total male workforce population (older than 15 yo)
	Employed males (older than 15 yo)
	Unemployed males (older than 15 yo) seeking for new employment
	Total population (older than 15 yo) not belonging to the total workforce
	Males (older than 15 yo) not belonging to the total workforce
	Total of home maker population (older than 15 yo)
	Total student population (older than 15 yo)
	Total male student population (older than 15 yo)
	Total population (older than 15 yo) under other conditions
	Total male population (older than 15 yo) under other conditions
	Resident population daily moving within the municipality of usual residence
	Resident population daily moving outside the municipality of usual residence
	Total population (older than 15 yo) recipients of income from work or capital
	Total male population (older than 15 yo) recipients of income from work or capital
Foreigners	Foreigners and stateless population resident in Italy – Total
	Foreigners and stateless population resident in Italy – Males
	Foreigners and stateless population resident in Italy – age 0 - 29 years
	Foreigners and stateless population resident in Italy – age 30 - 54 years
	Foreigners and stateless population resident in Italy – age > 54 years
	Foreigners and stateless population resident in Italy - males - age 0 - 29 years
	Foreigners and stateless population resident in Italy - males - age 30 - 54 years
	Foreigners and stateless population resident in Italy - males - age > 54 years
	Foreigners population resident in Italy – Europe
	Foreigners population resident in Italy – Africa
	Foreigners population resident in Italy – America
	Foreigners population resident in Italy – Asia
	Foreigners population resident in Italy – Oceania
	Stateless population resident in Italy
	Foreigners population resident in Italy – total
Dwellings	Dwellings occupied by at least one resident
	Empty dwellings and dwellings occupied only by non-residents

	Other types of occupied dwellings
	Empty dewllings
	Dwellings occupied only by non-residents
	Surface area of dwellings occupied by at least one resident
Families	Families in rented accommodation
	Families in owner-occupied housing
	Families occupying the accommodation in any other capacity
	Resident families – total
	Resident families – total family members
	Resident families - 1 member
	Resident families - 2 members
	Resident families - 3 members
	Resident families - 4 members
	Resident families - 5 members
	Resident families - 6 or more members
	Members of resident households of 6 and more
Buildings	Buildings and building complexes – total
	Utilized buildings and building complexes
	Residential buildings
	Buildings and building complexes for productive, commercial, office/tertiary, tourist/receptive, service, other uses
	Residential buildings in load-bearing masonry
	Residential buildings in reinforced concrete
	Residential buildings made of other materials (steel, wood, etc.)
	Residential buildings built before 1919
	Residential buildings built between 1919 and 1945
	Residential buildings built between 1946 and 1960
	Residential buildings built between 1961 and 1970
	Residential buildings built between 1971 and 1980
	Residential buildings built between 1981 and 1990
	Residential buildings built between 1991 and 2000
	Residential buildings built between 2001 and 2005
	Residential buildings built after 2005
	Residential buildings with 1 floor
	Residential buildings with 2 floors
	Residential buildings with 3 floors
	Residential buildings with 4 or more floors
	Residential buildings with an indoor
	Residential buildings with 2 indoors
	Residential buildings with 3-4 indoors
	Residential buildings with 5-8 indoors
	Residential buildings with 9-15 indoors
	Residential buildings with 16 or more indoors
	Total indoors of residential buildings
	Residential buildings in excellent state of preservation
	Residential buildings in good state of preservation
	Residential buildings in a medriocre state of conservation
	Residential buildings in a poor state of conservation

Table 1: ISTAT data

The system allows selections to be made even without knowing how to program queries in languages such as SQL, but acting via the interface of the power BI application. For example, as shown in Figure 9, it is possible to select only partially mountainous municipalities, subsequently filtering them by region, by clicking directly on the interactive map.

It was then decided to extract the overall result in a table exported so that it can be consulted even outside the proprietary Power BI software.



comune	tutteLeRegioniLocalita.LOCALITA	sigleProvince.PROVINCIA	tutteLeRegioniLocalita.ALTITUDINE	montanoParzialmente
Acquaviva Collecroce	Acquaviva Collecroce	Campobasso	425	CP
Acquaviva Collecroce	Case sparse	Campobasso	-	CP
Acquaviva Delle Fonti	Acquaviva delle Fonti	Bari	300	CP
Acquaviva Delle Fonti	Case sparse	Bari	-	CP
Acquaviva Delle Fonti	F. Miulli	Bari	420	CP
Acquaviva Delle Fonti	Pierantonio Frangi	Bari	421	CP
Adrano	Adrano	Catania	560	CP
Adrano	Calcerana-Marina	Catania	1060	CP
Adrano	Case sparse	Catania	-	CP
Adrano	Contrada Dagala	Catania	650	CP
Adrano	Passo Zingaro	Catania	630	CP
Adrano	Prato Fiorito	Catania	700	CP
Adrano	Sacro Cuore	Catania	600	CP
Agira	Agira	Enna	650	CP
Agira	Case sparse	Enna	-	CP
Agira	Sant'Anna	Enna	610	CP
Agosta	Agosta	Roma	382	CP
Agosta	Case sparse	Roma	-	CP
Agosta	Madonna della Pace	Roma	343	CP
Agosta	Tostini	Roma	360	CP
Agosta	Vasca	Roma	350	CP
Aidone	Aidone	Enna	800	CP
Ailano	Ailano	Caserta	260	CP
Ailano	Case sparse	Caserta	-	CP
Ailano	Cerqueta	Caserta	275	CP
Ailano	Le Vaglie	Caserta	162	CP
Ailano	Serretelle	Caserta	173	CP
Alassio	Alassio	Savona	6	CP
Alassio	Case sparse	Savona	-	CP
Alassio	Caso	Savona	240	CP
Alassio	Giancardi Sant' Anna	Savona	50	CP
Alassio	Regione Monti	Savona	50	CP
Alassio	Vegliasco	Savona	385	CP

Figure 9: Example of data extraction from Microsoft Power BI regarding only partially mountainous municipalities

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To facilitate the reading and understanding of the information underlying the territorial-medical analysis that the municipal administration is going to perform, a legend of all the types of analyzed data, and a brief description of the selection made for "Mountainous Municipalities" and "Marginal Municipalities", has been inserted (Figure 9).

The contribution of ISTAT data, which consider more detailed demographic and geographic data, provides an overview of the movements towards, and outside the various municipalities, in relation to the resident population.

These indications are important both for understanding the necessary movements towards hospital facilities, and for calculating the economic and time costs necessary for medical personnel to attend the elderly at their homes, which are often located in hamlets not easily reachable. The distribution of the population by age classes is useful, indeed, to have an estimate regarding how much people can easily move or not, while the combination of those data with those relating to diseases, allows to estimate the number of sick people for geographical area as illustrated in chapter 7. Moreover, other indications related to the purposes of prevention, and/or works to be implemented, are obtained from territorial data, for example, rainfall, the amount of snow, temperatures.

The information contained in the database, besides being generally useful to provide guidance to policy and decision-maker, is a tool that provides necessary data for the application of the Guidelines for Territorial and Healthcare Management illustrated in chapter 10.

3. Management and monitoring tools

A management system consists of a set of tools and processes that an organization implements to ensure quality, consistency, and continual improvement. Together with the monitoring systems they assure reliability of data and provide informed decision. If in the one hand, management system provide the guidelines on how to conduct the activities, namely it set policies, procedures and process to be followed; on the other hand, monitoring systems provide the raw data to work on.

Due to the high complexity of the phenomenon investigated within this report, a network management and monitoring tools may be the most comprehensive way to assess the system performances. Network management and monitoring tools are indeed defined as on-premises or cloud-based software platforms which connect with all the network components and other IT systems to measure, analyze, and report on network topology, functioning, and health. As suggested by the name, a network management and monitoring system comprises a variety of technologies and sensors, connected together within a centralized network. The great advantage of network management and monitoring system relies indeed on the variety of data gathered, which are able to provide the decision maker with an exhaustive comprehension of the system performances.

In the following paragraphs, both management system and monitoring system are explained in detail.

3.1 ISO Management system

Within this context, ISO management system may represent the most authoritative tool. ISO management systems are frameworks developed by the International Organization for Standardization (ISO) to assist organizations in effectively managing their operations. These systems are designed to promote consistency, efficiency, and continuous improvement.

The structure of ISO management systems follows a common framework known as the High-Level Structure (HLS). The HLS provides a standardized approach that facilitates integration and compatibility across different ISO management system standards. It consists of essential elements that include understanding the organization's context, demonstrating effective leadership, planning objectives and actions, providing necessary support, executing operations, evaluating performance, and driving improvement.

Within ISO management systems, there are specific systems focused on different areas of organizational management. For instance, the Quality Management System (QMS) is designed to ensure customer requirements are met and product/service quality is consistent. The Environmental Management System (EMS) aids in minimizing environmental impact and enhancing sustainability. The Occupational Health and Safety Management System (OH&S) prioritizes employee health, safety, and a secure work environment. Additionally, the Information Security Management System (ISMS) safeguards sensitive information and maintains data security.

3.2 Sensor Network and its components

A sensor network comprises multiple components which function synergistically to collect and transmit data, informing natural risks and population fragility in mountain areas. Specifically, the system is equipped with sensors for measuring environmental and e-health parameters, data loggers that gather, store, and transmit the data to a centralized system or network's platform. In addition, all the components of the sensor network must follow certain protocols, such as communication protocol for data transfer, or quality assurance techniques, to ensure data reliability and quality, and the proper functioning of the overall system.
The main components of the sensor network are described more in detail in the following paragraphs.

3.2.1 Sensors for Measuring Environmental and E-Health Parameters

Sensors play a crucial role in a sensor network by measuring various environmental parameters, as well as e-health ones, which are essential for understanding natural risks and the health status of the mountain population. In addition to sensors that measure environmental parameters such as rainfall, soil moisture, temperature, air quality, and seismic activity, the network can also include sensors for monitoring e-health parameters relevant to the specific health conditions prevalent in mountain areas. These e-health sensors can measure parameters such as heart rate, blood pressure, oxygen saturation, glucose levels, and respiratory rate.

3.2.2 Data Loggers for Data Storage and Transmission

Data loggers serve as the storage and transmission units within a sensor network. They are electronic devices equipped with a memory and a transmission system, responsible for data collection from the sensors and its storage. Data loggers hence capture the information provided by the sensor, and then they compress and store the gathered data.
Since they ensure reliable data storage and transmission even in remote or harsh conditions, they are suitable in monitoring mountain areas.

Whitin a sensor network, data synchronization among multiple data loggers is crucial to maintain a consistent timeline of collected data from both environmental and e-health sensors.

3.2.3 Communication Protocols for Data Transfer

Communication protocols are essential for transmitting data from data loggers to a centralized storage, or an analysis platform within the sensor network. Wireless communication protocols, such as Wi-Fi, LoRaWAN, or Zigbee, enable short or long-range data transmission, making them suitable for remote mountainous regions. These protocols ensure seamless data transfer from both environmental and e-health sensors to the data loggers and facilitate real-time or periodic transmission to centralized systems.

3.2.4 Sensor Calibration, Data Quality Assurance, and Data Synchronization

Sensor calibration is of utmost importance to ensure the accuracy and reliability of the collected data, for both environmental and e-health sensors. Data quality assurance techniques, such as outlier detection and data validation algorithms, are essential for identifying and correcting anomalies in the collected data from both environmental and e-health sensors. Additionally, data synchronization among multiple sensors and data loggers is critical to ensure a consistent timeline and reliable analysis of data related to both natural risks and health conditions.

3.3 Data Analysis for Risk Assessment

After data has been gathered, it has to be analyzed. Data analysis plays a pivotal role in risk assessment and decision-making, addressing both natural risks in the mountain environment and the health problems of the population. Through the integration of data from multiple sources such as sensor networks, satellite imagery, weather data, and health records, data analysis becomes more effective, enhancing risk assessment accuracy and providing valuable insights for informed decision-making.

Whitin the context of data analysis several tools and sources may be deployed. In the following paragraph the main methodologies of data analysis are briefly introduced to provide readers with a meaningful overview.

3.3.1 Statistical Analysis

Statistical analysis is a fundamental data analysis technique employed to uncover patterns, trends, and relationships within datasets related to natural risks and health problems.
In the context of natural risks, statistical analysis can be used to analyze historical data on rainfall, temperature, soil moisture, and other environmental parameters to identify risk thresholds and probabilities. Similarly, in health monitoring, statistical analysis can help identify patterns and correlations between health conditions, demographic factors, and environmental influences in mountain areas.

3.3.2 Machine Learning

Machine learning techniques have gained significant attention in recent years for their ability to analyze complex and large-scale datasets, making them valuable tools in risk assessment and health monitoring. In the context of natural risks, machine learning algorithms can process data from sensor networks, satellite imagery, and weather data to identify patterns, anomalies, and potential risk factors. These algorithms can be trained to recognize specific risk patterns, such as landslide-prone areas or flood-prone regions, based on historical data and environmental variables. In health monitoring, machine learning can assist in predicting disease outbreaks, analyzing patient health records, and identifying early warning signs.

3.3.3 Spatial Analysis

Spatial analysis techniques are crucial for understanding the spatial distribution of natural risks and health problems in mountain areas. This analysis involves the examination of geographic data, such as satellite imagery, topographic maps, and land use data, to assess the spatial relationships between environmental factors, population vulnerability, and risk exposure. In the context of natural risks, spatial analysis techniques can identify areas at high risk of landslides, floods, or other hazards based on slope stability, proximity to water bodies, and vegetation cover. In health monitoring, spatial analysis can help identify clusters of diseases, analyze access to healthcare facilities, and evaluate the impact of environmental factors on health outcomes.

3.3.4 Integration of Data from Multiple Sources for accurate risk assessment

The integration of data from multiple sources is essential for comprehensive risk assessment and health monitoring in mountain areas. By combining data from sensor networks, satellite imagery, weather data, and health records, a more holistic understanding of risks and health conditions can be achieved.

Among the multitude of methods and approaches data integration, some of the most frequently utilized by researchers and technicians are the following:

- **Data Fusion:** Data fusion involves combining information from different sensors, datasets, or sources to create a unified and enhanced dataset. This can be achieved through statistical techniques, such as data averaging, weighted aggregation, or data interpolation. Data fusion improves the accuracy and reliability of the data by reducing noise, filling data gaps, and providing a more complete representation of the hydrogeologic fragility factors.
- **Geographic Information Systems (GIS):** GIS is a powerful tool for integrating spatial data from multiple sources. It allows for the overlaying and integration of various datasets, such as geological maps, hydrological data, topographic information, and remote sensing imagery. GIS provides a spatial framework to analyze, visualize, and model the interrelationships between different risk factors and their spatial distribution in mountain areas.
- **Database Integration:** Integration of data from multiple databases is essential for comprehensive risk assessment. This involves combining data from different sources, such as field surveys, monitoring networks, remote sensing archives, and historical records. By integrating data into a centralized database, researchers and practitioners can access and analyze diverse data types simultaneously, facilitating a more comprehensive assessment of hydrogeologic fragility.
- **Data Mining and Machine Learning:** Data mining techniques and machine learning algorithms can be applied to integrate and analyze large volumes of heterogeneous data. These techniques can identify patterns, correlations, and anomalies in the data that may not be apparent through manual analysis. By leveraging these computational methods, valuable insights can be gained from the integrated data, aiding in more accurate risk assessment and prediction.
- **Expert Knowledge Integration:** Integrating data from multiple sources also involves incorporating expert knowledge and domain expertise. Experts in the field of hydrogeology, geotechnical engineering, and risk assessment can provide valuable insights and help interpret the integrated data. Their knowledge can contribute to identifying critical factors, validating results, and refining the risk assessment process.

3.4 Open-Source Technologies

Open-source technologies, such as Arduino and Raspberry Pi, are essential in the research's focus on leveraging cost-effective solutions for natural risk detection and telemedicine applications in mountain areas. Their potential for capturing relevant data, adds another layer of value to their adoption. Moreover, when open-source technologies, when developed and implemented under the guidance of ISO management systems, they offer a robust and standardized method for natural risk detection and monitoring.

These open-source platforms offer numerous advantages that make them particularly suitable for addressing fragility in these regions. This section expands on the advantages and challenges associated with the adoption of open-source technologies, highlighting their affordability, customization options, and the availability of community support. It also provides practical examples of open-source projects and initiatives in natural risk monitoring and telemedicine, showcasing their effectiveness in addressing fragility in mountain areas.

One significant advantage of open-source technologies is their affordability. Compared to proprietary solutions, Arduino and Raspberry Pi platforms are relatively inexpensive, making them accessible even in a resource-constrained mountain area. Their cost-effectiveness enables researchers, communities, and organizations to implement monitoring systems and telemedicine solutions that are both cost-effective and that offer a high level of customization and flexibility. These platforms provide a wide range of modular components and programming options, allowing researchers and developers to tailor solutions to specific needs and requirements.

Arduino and Raspberry Pi have large and active communities of users, developers, and enthusiasts who contribute to the development, documentation, and troubleshooting of projects.

Practical examples of open-source projects and initiatives in natural risk monitoring and telemedicine illustrate the effectiveness of these technologies in addressing fragility in mountain areas. For instance, researchers have successfully implemented open-source-based sensor networks, conforming to ISO standards, to monitor environmental parameters like rainfall, soil moisture, and temperature in mountainous regions prone to landslides. In the context of telemedicine, Raspberry Pi has been used to develop low-cost teleconsultation systems and remote patient monitoring devices. A more detailed discussion on Raspberry Pi application in environmental monitoring and telemedicine will be held in the next paragraphs.

3.4.1 Natural risks monitoring with Raspberry Pi

Raspberry Pi, as already mentioned, is an open-source technology widely used in environmental monitoring. Several are the examples of its practical application, which may vary in the specific environment to be monitored. For instance, Raspberry Pi, can be utilized to monitor air quality as well as geological stability or flood risk; it can be deployed in system with sensor or webcams for image processing applications.

These are just a few examples of how Raspberry Pi may be utilized for natural risks monitoring. The specific implementations may vary depending on the objectives, geographic context, and available resources. As technology continues to evolve, there may be additional innovative applications of this useful instrument.

In the following paragraphs the main fields in which Raspberry Pi is already utilized are described, and some related projects briefly presented.

Air quality monitoring

Raspberry Pi is widely used for air quality monitoring, and it is suitable for assessing atmospheric pollution rate both in indoor and outdoor environments. Numerous projects and tutorials demonstrate how to set up monitoring systems using Raspberry Pi.

For instance, Raspberry Pi can be used for monitoring air quality in indoor environments such as homes, offices, or schools. By combining sensors for temperature, humidity, carbon dioxide (CO_2), volatile organic compounds (VOCs), and particulate matter (PM), the system collects real-time data and provides insights into indoor air quality.

Similarly, Raspberry Pi can be implemented to monitor air quality in outdoor environments, especially by creating a dedicated air quality station. This involves deploying multiple Raspberry Pis equipped with sensors across different locations and it allows to gather comprehensive air quality data within the territory of interest. Data collected by each Raspberry Pi are then synchronized and analyzed centrally. Such projects often involve, data aggregation, and data visualization for detailed air quality analysis.

Two of the most known projects involving the utilization of Raspberry Pi for air quality monitoring are AirPi and OpenAQMonitor, they are briefly presented as follows:

- **AirPi** combines various sensors, including those for temperature, humidity, air pressure, carbon dioxide (CO_2), volatile organic compounds (VOCs), and particulate matter (PM), to measure and monitor air quality parameters. The Raspberry Pi collects data from these sensors and uploads it into a database or cloud platform for analysis and visualization.
- **OpenAQMonitor** is an open-source project that utilizes Raspberry Pi for monitoring air quality based on the OpenAQ platform. It combines a Raspberry Pi with a particulate matter (PM) sensor and a temperature/humidity sensor to collect and publish air quality data to the OpenAQ database. The project includes code and instructions for setting up the Raspberry Pi and connecting it to the OpenAQ platform.

The forementioned projects serve as starting points for using Raspberry Pi in air quality monitoring. They provide insights into hardware configurations, sensor selection, data collection, and data analysis techniques. Detailed instructions, code samples, and documentation for these projects are available on platforms like GitHub, Hackster.io, or the Raspberry Pi community forums.

Landslide Detection

Besides air quality, Raspberry Pi is a useful tool for monitoring geological stability, especially in terms of landslide detection.

Whitin this context Raspberry Pi has been used in webcam and image processing applications. In this regard, a great example is provided by the researchers of the University of Lausanne, Switzerland who have developed a Raspberry Pi-based system to monitor landslides. The system links Raspberry Pi to a webcam positioned near a landslide-prone area. The image processing algorithms implemented by the researchers on the Raspberry Pi can analyze the images and to detect changes in the terrain, such as the movement of soil or rocks. When significant changes are detected the system sent alerts, allowing for early warning and mitigation measures.

Other significant insights on Rasbperry Pi utilization for landslide detection can be retrieved within the following literature.

Real-Time Monitoring System of Landslide Based on LoRa Architecture
Frontiers | Real-Time Monitoring System of Landslide Based on LoRa Architecture (frontiersin.org)

Landslide Monitoring System Implementing IOT Using Video Camera
https://www.researchgate.net/publication/328961490_Landslide_Monitoring_System_Implementing_IOT_Using_Video_Camera

Bio-Inspired Robotic Solutions for Landslide Monitoring
https://www.frontiersin.org/articles/10.3389/feart.2022.899509/full

Landslides Detection in Prone Hilly Areas Using Raspberry Pi
https://link.springer.com/chapter/10.1007/978-981-15-0633-8_144

Cryosphere monitoring

Glacier Monitoring

Within the context of mountain areas, monitoring cryosphere resources is a key instrument to assess the changing conditions of glaciers under climate warming and other climate pressure. Glaciers monitoring, besides ensuring an effective environmental protection, provides crucial evidence on the impact and the speed of climate changing.

In the European Alps, not rarely researchers rely on Raspberry Pi to monitor glaciers. Raspberry Pi is connected to webcams placed near glaciers and set up to capture images at regular intervals. The captured images are then processed using image recognition algorithms to track several parameters, like glacier movement, ice melt, and changes in glacier size. As already noted, this kind of data provides insights on the climate change impacts on glaciers, supporting the assessment of the associated hazards.

To explore this topic further, a list of relevant articles on the topic is provided as following.

University of Leeds glacier research
https://www.raspberrypi.com/success-stories/university-of-leeds-glacier-research/

Raspberry Pi Helps Research Team Monitor Glaciers in Peru
https://www.tomshardware.com/news/raspberry-pi-glacier-monitoring

Ten-Year Monitoring of the Grandes Jorasses Glaciers Kinematics. Limits, Potentialities, and Possible Applications of Different Monitoring Systems
https://www.mdpi.com/2072-4292/13/15/3005

Avalanche Detection

Avalanches represent one of the main threats for mountains tourism, especially for ski-related tourism. Monitor the conditions of snowpack is thus crucial to ensure economic and environmental protection, as well as to assure safety among local population and tourists.

In this regard, a camera-based Raspberry Pi system can be employed for visual monitoring of avalanche-prone areas. By installing cameras and implementing computer vision algorithms, it is possible to detect changes in the landscape, such as cracks or movement, which may indicate avalanche risks.

A related meaningful project within this context is "AvaPi" avalanche detection system. Raspberry Pi, along with a webcam, is deployed in avalanche-prone areas to capture images of the snowpack. Image processing algorithms are then applied to analyze the images and identify signs of potential avalanche hazards, such as crack formation or changes in the snow structure. The system provided real-time alerts to avalanche forecasters and allowed for timely warnings and safety measures.

Other complementary monitoring tools for Avalanche detection: seismic and weather monitoring

Other monitoring system (i.e. seismic or weather monitoring) may be useful tool to be integrated within the avalanche detection system to gather more comprehensive data and to be able to evaluate potential and actual risks on reliable and complete information.

For instance, Raspberry Pi may be connected to seismic sensor or accelerometers to measure vibrations or detect movements associated with avalanches. In this way, the system is able to detect ground movements or seismic activity triggered by avalanches or, on the contrary, which may increase avalanche events.

Similarly, it is possible to rely on weather monitoring system in avalanche-prone areas to evaluate the related risks. Within this context, Raspberry Pi may be connected to weather sensors such as temperature, humidity, wind speed, and precipitation sensors, to collect data on overall weather conditions. Analyzing changes in weather patterns provides indications of potential avalanche risks.

To gather more specific information, the reading of the following article is highly suggested.
Raspberry Pi based Weather Monitoring using IOT
https://www.projectsof8051.com/raspberry-pi-based-weather-monitoring-using-iot/

Wireless Sensor Networks

By combining and integrating the forementioned tools it is possible to implement a wireless sensor network for avalanche detection, which probably is the most comprehensive monitoring system. This kind of system comprises a network of spatially dispersed and dedicated sensors linked to a centralized system or platform responsible for data analysis and risk assessment. So far, sensor networks are able to gather a variety of different information and thus to perform a more reliable evaluation.

In this regard, Raspberry Pi may serve as a central hub within the wireless sensor network deployed in avalanche-prone regions. Distributed sensors, including snow depth sensors, temperature sensors, and tilt sensors, can be deployed across the area. These sensors can communicate wirelessly with the Raspberry Pi to collect and analyze data related to snowpack stability, ground movement, or environmental conditions.

Wildfire Monitoring and Fire Detection

Fire is a part of nature, and it plays an important role in shaping ecosystems by acting as a catalyst for regeneration and change. However, fire may be devastating, destroying homes, wildlife habitats, and forests, contaminating the air with hazardous emissions and forcing populations displacement.

It is possible to distinguish two types of fires in nature: forest fires and wildfire. Forest fires are caused by natural or artificial fires linked to land clearing and deforestation, and they especially affect tropical, temperate, and coniferous forests. On the other hand, a wildfire is a spontaneous, uncontrolled fire in a natural woodland, grassland, or prairie setting. So, while the former is linked to deforestation, the latter is foster by climate warming.

In both situations it is crucial to implement a monitoring system to prevent disasters and mitigate risks, especially in terms of human casualties and ecosystem loss. Raspberry Pi has been used in monitoring system for both wildfire and fire detection.

Wildfire monitoring

Nowadays wildfires represent a serious environmental risk, which frequency and severity have been aggravated by climate change. Recent news events provide a picture of the extent of the worldwide situation, also showing the social impact of people being forced to move out and migrate from their homes.

In wildfire-prone regions, Wildfire and bushfire monitoring system is thus crucial to ensure an effective risk management, to preserve safety of both population and environment. It may empower administration on how to calculate losses and carry out disaster response efforts more effectively.

Within this context Raspberry Pi has been used in combination with webcams to monitor fire activity. The webcams are positioned strategically to capture images of the affected areas. Then Raspberry Pi runs an image processing algorithms to analyze the images and detect smoke or fire pixels. The system provided early detection of wildfires, allowing for faster response and firefighting efforts.

The following articles dealt with specific cases of wildfire detection, they thus provides more information and detailed instructions about, for example, code samples and hardware setups.

Wildfire Early Detection System (WEDS)
https://digitalcommons.calpoly.edu/cgi/viewcontent.cgi?article=1593&context=eesp

AN IOT BASED FOREST FIRE DETECTION AND PREVENTION SYSTEM USING RASPBERRY PI 3
https://www.irjet.net/archives/V6/i3/IRJET-V6I3624.pdf

IoT-inspired Framework for Real-time Prediction of Forest Fire

Forest Fire Detection using Machine Learning with Raspberry PI
https://ijarsct.co.in/Paper3837.pdf

Fire Detection with Thermal Imaging

In order to implement an effective fire detection, combining Raspberry Pi with thermal camera may be a useful strategy. The thermal camera captures infrared images, while Raspberry Pi analyzes the images for hotspots indicative of fires. By implementing image processing algorithms or machine learning models, it is possible to identify and alert about potential fire incidents. Moreover, there are several open-source projects and libraries for thermal imaging and object detection, which can be adapted to detect fire or heat in open areas.

To further investigate this topic and to have access to detailed instructions about how to implement fire detection systems with thermal imaging, the following articles are suggested.

Image Processing Based Fire Detection Using Raspberry Pi
https://nevonprojects.com/image-processing-based-fire-detection-using-raspberry-pi/

Fire Detection System using Raspberry Pi
https://ieeeprojectsmadurai.com/IEEE%202019%20IOT%20BASEPAPERS/31_Fire%20Detection%20System%20using%20Raspberry%20Pi.pdf

Smoke Detection with Image Processing

Smoke can be a useful indicator to be referred to in order to gather information about possible fires. In this case, Raspberry Pi, equipped with a regular camera, can be used for smoke detection in open areas. The camera captures images, and the Raspberry Pi processes them to identify smoke patterns. Image processing techniques, such as color segmentation or edge detection, are employed to detect smoke plumes. By continuously analyzing the images, the system is able to trigger fire alarms or send notifications when smoke is detected.

To deepen the topic and gather more information on smoke detection system, the following article may be a useful tool.

Fire and Smoke Detection System Using Image Processing
https://ijcrt.org/papers/IJPUB1704001.pdf

Gas and Temperature Monitoring

Raspberry Pi can be also integrated with gas sensors and temperature sensors to monitor fire-related indicators in the environment. Gas sensors detect gases emitted during combustion, such as carbon monoxide or flammable gases, while temperature sensors detect rapid increases in temperature. By combining the readings from these sensors, the Raspberry Pi is able to trigger alarms or alerts when fire-related conditions are detected.

More specific information on gas and temperature monitoring can be retrieved in the following article.

Enviro for Raspberry Pi
https://shop.pimoroni.com/products/enviro?variant=31155658489939

Wireless Sensor Networks for Fire Detection

Another useful option to implement fire monitoring system consists in the combination of the forementioned tools within a wireless sensor network. As already mentioned, Wireless sensor networks refer to networks of spatially dispersed and dedicated sensors which function synergistically to collect and transmit data to a central system or cloud platform. This may be the most comprehensive way to perform a fire monitoring system, since it relies on a great variety of different data.

Raspberry Pi can act as a central node within a wireless sensor network for fire detection in open spaces. Multiple sensors, such as temperature sensors, smoke sensors, or gas sensors, can be distributed in the area and wirelessly communicate with the Raspberry Pi, which collects and processes the received data. Based on predefined thresholds or algorithms, it is able to identify potential fire incidents and take appropriate actions.

Flood monitoring

Flooding is the world's most costly type of natural disaster according to the European Spatial Agency. Flood indeed can strike with deadly regularity, destroying housing, agriculture, and communications. To ensure population and infrastructure protection, as well as to avoid negative impacts on the local environment, it is crucial to implement a monitoring system. In this way, well in advance of any flood occurring, the system can help administrations and, particularly civil protection planners, to anticipate critical condition of a river. For instance, satellites or other kinds of sensors can anticipate where a river would be most prone to burst its banks or evaluate eventual anomalous rise in water levels or precipitations.

There are several projects and examples of flood monitoring system implemented with Raspberry Pi; below the most significant are briefly presented. A more comprehensive list of projects related to Raspberry utilization within flood monitoring may be retrieved on platforms like GitHub, Hackster.io, or Instructables.

Pi-FloodCam

Pi-FloodCam is a project that combines Raspberry Pi with a webcam to monitor flood situations. It captures images at regular intervals and uploads them to a remote server or cloud storage. By analyzing the images, it is possible to detect changes in water levels over time. The project also includes a web interface to view the images and visualize the flood progression.
To explore further the project, it is possible to consult the following article:

Use of a Raspberry-Pi Video Camera for Coastal Flooding Vulnerability Assessment: The Case of Riccione (Italy)
https://www.mdpi.com/2073-4441/14/7/999

Raspberry Pi Flood Monitoring System

This project focuses on monitoring water levels using ultrasonic sensors connected to a Raspberry Pi. The latter collects data from the sensors and uploads it into a cloud platform, such as ThingSpeak or Adafruit IO, to allow remote access and analysis. The project includes a web-based dashboard to visualize the water level data in real-time.

Raspberry Pi Weather and Flood Warning System

This project combines weather monitoring with flood detection. It utilizes Raspberry Pi to collect weather data, including rainfall measurements, and water level sensors to monitor flood conditions. The data is processed and analyzed on the Pi, and alerts are generated when critical thresholds are reached. In addition, the system can send notifications via email or SMS, thus ensuring early warning.

The following two articles dealt with this project and they me be consulted to gather specific information:

IoT-based Flood Monitoring and Alerting System using Raspberry Pi
https://iopscience.iop.org/article/10.1088/1757-899X/981/4/042078/meta

FLOOD MONITORING AND EARLY WARNING SYSTEM USING RASPBERRY PI
https://electronicsworkshops.com/2021/09/12/flood-monitoring-and-early-warning-system-using-raspberry-pi/

Smart Flood Monitoring System

This project integrates Raspberry Pi with various sensors, including water level sensors, rain sensors, and temperature sensors, to create a comprehensive flood monitoring system. The Raspberry Pi collects data from the sensors, processes it, and sends alerts in real-time. The project also includes a web interface to display sensor readings and historical data.

More information about this project can be found within the following article:

Smart IoT Flood Monitoring System
https://iopscience.iop.org/article/10.1088/1742-6596/1339/1/012043/pdf

3.4.2 E-Health Project based on Raspberry Pi

Raspberry Pi represents a useful instrument also in the field of medicine, where it can be deployed to monitor various parameter within a telemedicine system. Parameters to be monitored may be several, especially depending on the specific medical condition being addressed and the technology used.
The most frequently monitored e-health parameters are described below, to provide readers with an overview of telemedicine monitoring.

- **Vital signs**
  Telemedicine often involves the remote monitoring of vital signs such as blood pressure, heart rate, respiratory rate, oxygen saturation, and body temperature. These measurements can be obtained using wearable devices or connected medical devices.
- **Blood glucose levels**
  For patients with diabetes or other conditions requiring glucose monitoring, telemedicine systems may include the measurement of blood glucose levels using glucometers or continuous glucose monitoring (CGM) devices. The readings can be transmitted to healthcare providers for remote monitoring and management.
- **Electrocardiogram (ECG)**
  ECG readings can be recorded and transmitted in real-time or stored for later review. This allows healthcare providers to assess cardiac health, detect irregularities, and provide timely intervention when necessary.
- **Pulmonary function**
  Telemedicine can enable the measurement of pulmonary function parameters such as spirometry, peak expiratory flow rate (PEFR), and forced expiratory volume (FEV1). Patients can perform these tests using portable spirometers connected to the telemedicine system.
- **Imaging and diagnostic**
  Telemedicine can facilitate the transmission and interpretation of various medical images, including X-rays, ultrasounds, CT scans, and MRIs. Specialists can review the images remotely, provide diagnoses, and guide further treatment.
- **Weight and body composition**
  Telemedicine systems may incorporate devices for measuring weight, body mass index (BMI), and body composition (such as fat percentage). These measurements can assist in managing conditions related to weight and nutrition.
- **Medication adherence**
  Telemedicine platforms can support medication adherence monitoring, reminding patients to take their medications and tracking their adherence to prescribed regimens. This may involve interactive reminders, smart pillboxes, or medication tracking apps.
- **Mental health assessment**
  Telemedicine can enable remote assessments of mental health conditions using standardized questionnaires or assessments administered through video conferencing or mobile apps. This can include measures of depression, anxiety, cognitive function, and overall psychological well-being.

Integrating monitoring systems and telemedicine solutions, guided by ISO management systems, within the context of fragility in mountain areas provides a comprehensive approach to risk management and healthcare delivery. It enables early warning, remote patient monitoring, improved coordination, data-driven decision making, cost-effectiveness, and resource optimization. This integration ultimately contributes to the resilience, well-being, and safety of populations living in these vulnerable regions.

Raspberry Pi may be utilized within telemedicine system to implement health parameters monitoring. For instance, a telehealth kit piloted in NHS based on Raspberry technology have been developed. To gather more specific information and instructions about the utilisation of Rasbperry within E-health monitoring system, it is possible to refer to the following articles.

https://www.raspberrypi.com/news/raspberry-pi-telehealth-kit-piloted-nhs/

How Raspberry PI Telehealth Kit Will Boost Health IoT
https://intersog.com/blog/how-raspberry-pi-telehealth-kit-will-boost-health-iot/amp/

4. Involved municipalities

The FragMont project involved the municipalities of Moncucco Torinese (AT) and Alagna Valsesia (VC) as pilot sites. These territories show some specific peculiarities, widely different from each other. The choice of these realities depended on the aim to develop a system able to respond to a variety of needs and situations. In the future, this will allow to replicate the same approach to other targeted municipalities.

Specifically, the investigation work focused on the elderly population, studying the main pathologies and other aspects inherent to fragility, which is related to the progressive ageing of mountain populations. The municipalities of Valsesia Valley have been considered exclusively during the exploratory analysis, just to assess a preliminary verification.

Moncucco Torinese is a hillside municipality which presents a less critical situation than that of Alagna Valsesia in terms of hydrogeological instability. The area of Moncucco Torinese is indeed affected by small landslides, which can form quickly following rainfall. The access to the municipality is facilitated by the presence of several roads and, because of this, a monitoring system, allowing for the effective calculation of maintenance costs, must be implemented.

To reach Alagna Valsesia only one access route is available, this may considerably complicate any rescue activities and the reaching of fragile people living in these territories, especially the most isolated ones. Being a mountain municipality, the hydrogeological risk makes the territory itself much more vulnerable: Alagna Valsesia is not affected just by small landslide events, but it may experience avalanches, and slow or extensive floods and landslides. This is a particularly fragile territory which requires constant and active care, especially considering its importance as a tourist area given by its proximity to Monte Rosa.

Figure 10: Alagna Valsesia

Figure 11: Alagna Valsesia

Figure 12: Moncucco torinese

Figure 13: Wall subject to small-scale collapse in the Moncucco area

4.1 Available data for the analyzed municipalities

The research group has precise data on the Alagna Valsesia area. This data, presented within a geological report, allow to enumerate the sites where damage has occurred within the municipal territory and the related restoration work carried out. This kind of information is very important, as readers will learn later in this report, because it allows to calculate man-hours and machine-time spent in restoring the damage following the occurrence of natural disaster, such as landslides.

From a medical point of view, data on the average composition of the population by age group, and the average manifestation of pathologies by age groups are available just for the case of Moncucco Torinese, while the same information is not available for the territory of Alagna Valsesia. However, as described in detail later, this data may be extrapolated from the study and mapping available at national level.

5. Survey on territorial fragility

The territory, particularly the Italian one, is affected by various impacts which determine its fragility. This characteristic then reverberates on the anthroposphere with consequences on settlements, infrastructures, and ultimately, on the safety of citizens themselves.

The variables that most shape the fragility of a territory can be summarized in two macro categories: climatic and geological. Regarding the former, intense, or extreme weather events, or absence of rain for excessively long periods, trigger risk conditions for the territory. In the first case, with a direct impact on the stability of slopes or on the exceeding of the ordinary flow situation in watercourses; in the second case, predisposing the territory to future instabilities determined by the reduced ability of soils to offer adequate resistance to erosive phenomena. In the event of snowy precipitation, there can be an additional casuistry due to the instability of snow accumulations, from which avalanche phenomena may arise. In addition to precipitation, wind can also determine or predispose the risk of instability, especially when acting on the forest cover. Many trees uprooted by a storm exposes significant portions of soil, that may be subject to erosion phenomena or constitute entry points for water that may act in depth destabilizing a part of the slope

Figure 14: Pine forests felled by the Vaia storm in autumn 2018

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Figure 15: Pine forests felled by the Vaia storm in autumn 2018

Figure 16: Flood impacts on a marginal municipality. Image automatically generated by Bing AI

Within the current scenario of global warming, the rising temperature also indirectly generates a risk condition. The persistence of warm conditions at high altitudes causes a degradation of the permafrost on rock walls and determines favorable conditions for the collapse of rock masses. The same impact occurs on glaciers, where an increase in sliding speed, and an increase in serac collapse phenomena, are recorded.

On the other hand, the geological sphere encompasses different phenomena affecting the territorial stability. Among others, landslide, with all its different phenomenology due mainly to the type of material involved (rock, debris, earth or combination of the previous ones), and the speed of movement (Table 2), is particularly impactful.

In addition to the above phenomena, for high-altitude territories, avalanche phenomena and serac collapses have also to be considered. Seismic risk is also to be mentioned, but just for those localities where such risk is of particular significance.

Class	Description	Observable Damages	Speed	(m/s)
7	Extremely fast	Catastrophe of exceptional violence. Buildings destroyed by the impact of the displaced material. Many deaths. Escape impossible.	5 m/s	5
6	Very fast	Loss of some human lives. Speed too high to allow evacuation of people	3m/min	5×10^{-2}
5	Fast	Evacuation possible. Destruction of structures, buildings, and permanent installations.	1.8 m/h	5×10^{-4}
4	Moderate	Some temporary or less vulnerable structures can be maintained.	13m/month	5×10^{-6}
3	Slow	Possibility of undertaking reinforcement and restoration works during movement. Less vulnerable structures can be maintained with frequent reinforcement works if the total movement is not too large during a particular acceleration phase.	1.6 m/year	5×10^{-8}
2	Very slow	Some permanent structures may not be damaged by the movement.	16 mm/year	5×10^{-10}
1	Extremely slow	Imperceptible without monitoring instruments. Building construction possible with precautions.		

Table 2: Scale of landslide intensity based on velocity and damage produced (Cruden, 1996)

So far, mountain areas are particularly susceptible to various natural risks, which pose significant threats to both human communities and the environment. These risks include floods, landslides, erosion, and contamination, each having its own distinct characteristics and impacts. Flooding in mountain regions can occur due to heavy rainfall, snowmelt, or the overflow of rivers and streams, leading to property damage, infrastructure disruption, and potential loss of life. Landslides, triggered by factors such as steep slopes, unstable soils, and intense precipitation, can cause devastating consequences, including mass movements of soil and rock that can bury buildings and block transportation routes. Erosion, resulting from water and wind forces, can gradually wear away the soil and negatively impact agricultural productivity, water quality, and ecosystem stability. Additionally, contamination, whether from industrial activities, mining operations, or improper waste disposal, can pollute water sources and pose significant health risks to local communities.

Understanding the key factors that contribute to shaping mountains fragility is essential for effective risk management and the development of appropriate monitoring systems. The following factors play a significant role in hydrogeologic fragility in mountain areas:

- **Slope Stability**
  The steep slopes commonly found in mountainous terrain make it susceptible to landslides, rockfalls, and slope failures. Factors such as geological composition, weathering, seismic activity, and water infiltration influence slope stability. Inadequate slope stability can lead to significant hazards for communities living in these areas.
- **Groundwater Dynamics**
  The presence of groundwater and its movement in mountain areas significantly influences hydrogeologic fragility. The interaction between surface water and groundwater can affect slope stability and trigger mass movements. Changes in groundwater levels, such as during periods of heavy rainfall or snowmelt, can increase the risk of landslides, debris flows, and flooding.
- **Erosion and Sedimentation**
  The erosive forces of water, combined with the steep topography of mountain areas, contribute to erosion and sedimentation processes. Erosion can weaken slopes and contribute to landslides, while sedimentation can obstruct watercourses and increase flood risks. Human activities, such as deforestation and improper land use, can exacerbate erosion and sedimentation in mountain areas.
- **Climate Change**
  Climate change impacts are particularly pronounced in mountain regions, leading to alterations in precipitation patterns, temperature, and glacier dynamics. These changes affect the hydrological cycle, snowpack accumulation, and permafrost stability. Climate change-induced variations can intensify hydrogeologic fragility, including increased flood risks and changes in groundwater dynamics.
- **Natural Hazards**
  Mountain areas are prone to various natural hazards, including earthquakes, avalanches, and volcanic activity. These hazards can have a direct impact on

hydrogeologic fragility, causing ground instability, altering groundwater dynamics, and triggering secondary hazards such as landslides and debris flows.

Understanding the interplay of these factors is crucial for assessing hydrogeologic fragility in mountain areas. The integration of monitoring systems, such as wireless sensor networks and satellite image processing, can provide valuable data on these factors, enabling better risk assessment and management strategies to mitigate the impacts of hydrogeologic fragility.

Figure 17: Flood affecting a mountain municipality. Image automatically generated by Bing AI

To minimize the effects of the phenomena described and mitigate their impacts on the territory, and consequently on the population, different strategies can be adopted but, in any case, it is necessary to undertake a monitoring campaign to better understand the characteristics and their evolution over time, also in function of structural interventions.

Monitoring, with different tools, allows to pursue the aforementioned objectives and to provide fundamental numerical data for the correct study of the investigated phenomena (Table 3). Thanks to recent technological development, several monitoring tools/methods are now available. If they are used synergistically, they can provide an in-depth description of the kinematics, magnitude and evolution of the phenomenon, mutually compensating for their intrinsic limits, e.g., integration of surface and deep monitoring (Allasia et al., 2021) or remote and in situ (Godone et al., 2020).

Measurements on the surface	1 Distometric measurements
	2 Strain gauge measurements
	3 Crack-meter measurments
	4 Wall inclinometric measuremen3ts
	5 Traditional topographic measurements
	6 GPS/GNSS measurements
	7 Lidar measurements
	8 Interferometric measurements from the ground
	9 Interferometric measurements from satellite
	10 Measurements with Doppler radar
	11 Measurements by means of drones – UAV" in English.
	12 Measurements by means of photomonitoring
	13 Measurements for rapid flows
	14 Measurements with optical fiber sensors
Deep measurements	1 Inclinometric measurements
	2 Multiparametric measurements
	3 Time Domain Reflectrometry
	4 Multibase strain gauge measurements
	5 Settlement measurements
	6 Piezometric measurements
	7 Suction measurements
Meteorological and pluviometric measurements	1 Pluviometric measurements
	2 Anemometric measurements

Table 3: Measurement activities used in the study of landslides (Dei Cas L. et al., 2021)

It is important to specify that each landslide phenomenon requires different types of measurement, and that some of these tools are unsuitable for certain types of landslides. For instance, the use of an inappropriate measure, like the use of inclinometer measures for landslides with rapid kinematics, leads to the collection of non-significant data and the nonrational use of resources, or rather it means that no meaningful monitoring can be carried out. In addition to surface and deep measurements, meteorological-rainfall measurements are also indicated, because they allow the collection of ancillary information useful for improving the general knowledge of the phenomenon and the surrounding site.

The listed approaches are also applicable to the monitoring of structures/infrastructures directly connected to landslide phenomena, such strategy allows to quantify the impacts of phenomena on sensitive objectives and, in some cases to indirectly monitor some difficult-to-monitor phenomena, e.g., rock falls. Understanding the impacts on the anthropic environment also allows the planning and quantification of maintenance interventions - ordinary and extraordinary, preventive, and restorative (Giordan et al., 2021). These strategies are of fundamental importance for the mitigation of territorial fragility and the reduction of the marginality of the aforementioned territories.

Figure 18: Landslide example. Image automatically generated by Bing AI

In addition to a correct design and execution of monitoring, the communication of results in the most suitable forms to reach different targets of the population, such as expert, slightly expert or non-expert, ensuring informed cohabitation to the population (Giordan et al., 2019).

Data analysis plays a crucial role in risk informatics architecture, as it enables the interpretation and synthesis of collected data to generate meaningful insights and actionable information. Advanced data analysis techniques, such as statistical analysis, machine learning algorithms, and spatial analysis, can be applied to identify risk patterns, predict potential hazards, and support decision-making processes. By integrating these various components, an effective risk informatics architecture can provide real-time monitoring capabilities, enabling the early detection of potential risks and facilitating the timely implementation of appropriate mitigation measures.

In addition to instrumental monitoring, it is also necessary to recall the importance of territorial surveillance by specialized personnel (Giordan et al., 2020) to ensure extensive control on the territory and to highlight those phenomena that due to extension, frequency or magnitude are not easily detectable, or for which it is not significant to activate instrumental monitoring campaigns.

6. Investigation on Population Vulnerability

In mountain regions, population fragility refers to the vulnerability of individuals and communities to health risks and limited access to healthcare services. These areas often face unique healthcare challenges due to geographical remoteness, limited infrastructure, and inadequate healthcare resources. Telemedicine solutions can play a crucial role in addressing these challenges and improving healthcare access and outcomes. Here is an overview of population fragility in mountain regions and the potential contributions of telemedicine solutions:

- **Geographical Isolation**
  Mountain regions are often characterized by geographical isolation, with scattered and dispersed populations. This isolation can hinder timely access to healthcare facilities and specialized medical expertise. Telemedicine can bridge this gap by enabling remote consultations, virtual diagnosis, and follow-up care, reducing the need for patients to travel long distances.
- **Limited Healthcare Infrastructure**
  Mountain areas may have limited healthcare infrastructure, including hospitals, clinics, and medical professionals. Telemedicine allows healthcare providers to reach patients in remote areas virtually, overcoming the limitations of physical infrastructure. This facilitates the delivery of essential healthcare services, including primary care, specialist consultations, and chronic disease management.
- **Emergency and Disaster Response**
  Mountain regions are prone to natural disasters, such as landslides, avalanches, and earthquakes, which can disrupt healthcare services and increase the need for emergency response. Telemedicine solutions can support emergency response efforts by enabling real-time communication between healthcare providers, emergency responders, and remote patients. Teleconsultations can help assess and triage patients, provide remote medical guidance, and facilitate coordination among healthcare teams during crises.
- **Limited Specialist Availability**
  Access to specialized healthcare providers, such as cardiologists, neurologists, and oncologists, can be challenging in mountain regions. Telemedicine allows patients to remotely consult with specialists, regardless of their physical location. This enhances the availability and affordability of specialized care, ensuring that patients receive timely diagnosis, treatment, and ongoing management of their conditions.
- **Chronic Disease Management**
  Mountain populations may have a higher prevalence of chronic diseases due to various factors, including lifestyle, environmental conditions, and limited access to preventive care. Telemedicine solutions can support remote monitoring and management of chronic conditions through wearable devices, remote patient monitoring systems, and teleconsultations. Patients can regularly share their vital

signs, receive education and self-care instructions, and have virtual follow-up visits with healthcare providers.

- **Health Promotion and Education**
  Telemedicine extends beyond direct clinical care and can be leveraged for health promotion and education initiatives in mountain regions. Telehealth platforms can provide educational resources, preventive health campaigns, and remote training programs for healthcare professionals in these areas. This empowers individuals and communities to take charge of their health, prevent diseases, and adopt healthy lifestyles.

Location	Altitude (M.S.L.M.)	Surface area (Km^2)	Population (As of 01/01/21)	Population density (Ab/Km^2)	Elderly population (Age > 65 years)	% Elderly/Total
Italia	/	302.068,2564	59.236.213	196,10	1.3941.531	23,54%
Piemonte	168,32	25.387,07	4.274.945	168,39	1.112.287	26,02%
Asti (provincia)	280	1.510,19	209.390	138,65	55.946	26,72%
Vercelli (provincia)	378	2.087	165.584	79,82	45.906	27,56%
Torino (provincia)	478	6.830,53	2.219.206	324,90	571.992	25,77%
Moncucco Torinese (AT)	403	14,36	878	61,14	247	28,13%
Alagna Valsesia (VC)	1.191	133,17	725	5,44	168	23,17%
Giaveno (TO)	506	71,97	16.168	224,65	4.397	27,20%
Fenestrelle (TO)	1.154	49,04	483	9,85	159	32,92%
Usseglio (TO)	1.265	98,54	200	2,03	68	34,00%

Table 4: ISTAT 2022 data

The investigation on population vulnerability serves multiple purposes. On one hand, it provides useful data to feed the decision-making process and, more generally, to prepare actions for the vulnerable population, both preventive and in response to emergencies. On the other hand, within the Project, it is crucial because, based on its results, it is possible to identify the variables of greatest interest for the implementation of the telemedicine prototype.

The demographic profiles of mountain municipalities confirm the higher presence of elderly individuals compared to urban areas. The inherent vulnerability of this population (higher prevalence of chronic diseases, related care and assistance needs, lack of self-sufficiency, disabilities, etc.) adds to the vulnerabilities of the territory (downsizing and defunding of local healthcare services, distance between peripheral mountain areas and hospital facilities, increased incidence of natural disasters and potential challenges in managing health issues). These vulnerabilities, as one can understand, are among the main reasons for migration to areas with more immediate access to social and healthcare facilities and contribute to the abandonment of mountain regions.

The analyzed context is that of Piedmont; some necessary references will be made in relation to broader national and international scenarios.

In Italy, there are 3,538 municipalities located in mountain areas, accounting for 43.7% of all municipalities. They are distributed across all regions, with a prevalence in the territories of northern Italy. Although the percentage of mountain municipalities is higher in other regions of northern, central, or southern Italy, Lombardy and Piedmont have the highest number of mountain municipalities (527 and 503 respectively) (Institute for Local Finance and Economy [IFEL] - National Association of Italian Municipalities [ANCI], 2014).
In Piedmont, mountain municipalities account for 41.5%, while non-mountain municipalities represent 58.5% (IFEL - ANCI, 2017). The numbers may vary depending on the classification criteria adopted (municipalities fully or partially located in mountain areas, mountain municipalities based on membership in mountain unions/communities, mountain municipalities based on the predominant altimetric location of the municipal territory, etc.). However, they provide an overview in which mountain and hilly territories, as a whole, are predominant.

In light of these numbers, if we consider the ratio between the territorial area and the number of resident populations by altitude zone, we observe an equally significant phenomenon. In Piedmont, despite the mountainous area covering 43.2% of the territory (while hilly and flat areas account for 30.3% and 26.5% respectively), the resident population in the mountainous areas represents only 11.1% of the total population (30.6% in hilly areas and 58.3% in the plains) (National Institute of Statistics [ISTAT], 2019). This data reflects a well-established trend, so much so that we now refer to it as the phenomenon of "depopulation of the Mountains.”

This phenomenon, as previously mentioned, is linked to a series of challenges that, over the past decades, have increasingly driven young people to move to cities in the plains or less isolated living environments. As a result, the proportion of elderly individuals has increased more than the rest of the population. It should be noted that this phenomenon appears to be widespread and progressively increasing in other geographic areas and at different altitudes.

The aging of the Italian population, as a characteristic feature of the demographic dynamics in the coming decades, can be understood by examining some highly reliable indicators:

- The population aged 65 and over, between 2015 and 2065, will increase from 21.7% to 32.6%.
- The ratio between the population aged 65 and over and the population of working age between 15 and 64 years old (the old-age dependency ratio), which was 33.7% in 2015, will reach 59.7% in 2065.
- The average age of the population, life expectancy at birth, and life expectancy at 65 years old, which have already reached very high levels, will continue to increase over the next fifty years (ISTAT, 2015).

In mountainous areas, as previously mentioned, population aging is also linked to depopulation and/or emigration phenomena, which mostly affect young people and adults. As a result, the percentage of elderly population in relation to the total population will increase. There seems to be a countertrend of repopulation, partly facilitated by regional policies, but it appears to be sporadic cases that are not able to counteract the exodus witnessed in past decades.

In this regard, a document prepared by the World Health Organization (WHO) on the territorial care and assistance of the elderly provides valuable insights: "With increasing age, numerous physiological changes occur, and the risks of developing chronic diseases and dependency on care increase for older people. From the age of 60, the main causes of disability and death are related to hearing, vision, and mobility impairment, as well as conditions such as dementia, cardiovascular diseases, stroke, chronic respiratory diseases, diabetes, and musculoskeletal disorders such as osteoarthritis/arthritis and back pain" (World Health Organization [WHO], 2017).

This trend is also confirmed in Italy. The National Institute of Health (2021), in a report from 2021, states that "in the period before the pandemic, data from the PASSI d'Argento surveillance system (on the 2016-2018 sample of approximately 40,000 individuals aged sixty-five and over) show a long-lived country, but with a significant proportion of older adults with chronic diseases and multimorbidity, which increases their vulnerability to adverse health events."

Among those aged 65 to 75, "over half of the individuals live with one or more chronic diseases among those investigated, and this proportion increases with age, ultimately affecting three-quarters of individuals over eighty, with half of them affected by two or more chronic diseases" (ISS, 2021).

The National Observatory on Health in Italian Regions (2019) had previously observed that "chronic diseases [in 2018] affected almost 40% of the population in Italy, which is 24 million Italians, of whom 12.5 million have multiple chronic conditions. Projections on chronicity indicate that in ten years, by 2028, the number of chronic patients will rise to 25 million, while the number of individuals with multiple chronic conditions will be 14 million."

These issues are also linked to economic and organizational management aspects: "40% of healthcare spending [in Italy] is allocated to the elderly and the very elderly. It is worth noting that public healthcare spending is 10% lower than the European average, while the percentage of costs borne by patients is the highest" (Italian Society of Gerontology and Geriatrics [SIGG], 2018).

The National Observatory on Health in Italian Regions at the Catholic University of the Sacro Cuore (2019) also highlights that "Currently, in our country, it is estimated that approximately €66.7 billion are spent on chronic diseases. Based on future demographic scenarios developed by the National Institute of Statistics (ISTAT) and assuming a stable prevalence in different age groups, it is projected that we will spend €70.7 billion in 2028."

The criticality of these phenomena and the fact that they will likely represent one of the major challenges awaiting the National Health Service (SSN) in the future is evident from the limited information provided. The issue of chronicity has numerous facets, some of which closely concern the realities considered in our research project. According to the National Observatory on Health in Italian Regions (2019):

"Communities with fewer than 2,000 inhabitants have the highest proportion of chronicity, nearly 45%, while in the outskirts of Metropolitan cities, the highest proportion of people suffering from allergic diseases is found, accounting for 12.2% of the resident population."

Secondly, as already highlighted in the WHO guidelines (2017), the average age and the onset of one or more chronic diseases are phenomena characterized by a substantial direct proportionality, especially from the age of 55-60. It is no coincidence that the beginning of old age has conventionally been set at the age of 65, although this datum has been and is increasingly debated by experts due to the increase in average quality and duration of life in Western countries (SIGG, 2018). We will refer to it for analytical purposes.

6.1 Population affected by chronic diseases

We preferred to consider the ISTAT population as of 01/01/2021 instead of 01/01/2019 (like the percentage of the population with ≥ 1 chronic diseases) because the Municipality of Alagna Valsesia has experienced an increase in population from 448 to 725 residents (+66% population aged 0-60 years; +50% population ≥ 60 years) between 2019 and 2021.
On the other hand, the municipality of Moncucco Torinese, being more stable, went from 891 to 878 residents during the same period.

Below are some data regarding prevalence. Prevalence is a measure of frequency used in epidemiology to express the ratio between the number of individuals affected by a disease event in a given population during a specified time interval and the total number of individuals in the population during the same period.

ISTAT Population (01/01/2021)				
Location	**Age Groups**			
	50-64	**65-74**	**75-84**	**≥ 85**
Italia	13.198.468	6.915.504	4.825.173	2.200.854
Piemonte	971.027	534.834	396.698	180.755
Alagna Valsesia	183	83	64	21
Moncucco Torinese	206	131	88	28

Table 5: ISTAT data on population over 50 years old affected by chronic diseases - Italy, Piedmont, Alagna, Moncucco Torinese[3]

Percentage of population with ≥ 1 chronic conditions (01/01/2019)				
Location	**Age Groups**			
	50-64	**65-74**	**75-84**	**≥ 85**
Italia	26%	54%	66%	72%
Piemonte	24%	44%	55%	51%

Table 6: Prevalence of population with multiple chronic diseases among those over 65 (percentage) - Italy, Piedmont

[3] https://www.epicentro.iss.it/coronavirus/pdf/passi/sars-cov-2-flussi-dati-confronto-passi-pda-patologie-croniche.pdf

Estimate of the chronic population (not institutionalized)				
Location	**Age Groups**			
	50-64	**65-74**	**50-64**	**≥ 85**
Italia	3.431.602	3.734.372	3.184.614	1584.615
Piemonte	233.046	235.327	218.184	92.185
Alagna Valsesia	44	37	35	11
Moncucco Torinese	49	58	48	14

Table 7: Data analysis ISTAT 2019 - Estimated population of non-institutionalized individuals with chronic conditions among those over 50 years old (number)

Prevalence of clinical conditions/chronic diseases in the elderly population (≥ 65 years) in Piemonte data in percentage (2016-18)	
Location	Piemonte
Clinical condition/chronic pathology	
Hypertension	59%
Cardiopathies	22%
Tumors	14%
Diabetes	12%
Chronic respiratory diseases	10%
Stroke or cerebral ischemia	6%
Renal failure	4%
Chronic liver diseases and/or cirrhosis	2%

Table 8: Prevalence of clinical conditions/chronic diseases in the elderly population (≥ 65 years old). Data in percentage (2016-18)

Estimate of the population with chronic conditions (non-institutionalized)			
Localities	**Piemonte**	**Alagna Valsesia**	**Moncucco Torinese**
Clinical condition/chronic pathology			
Hypertension	656.24	99	146
Cardiopathies	244.703	37	54
Tumors	155.720	24	35
Diabetes	133.474	20	30
Chronic respiratory diseases	111.229	17	25
Stroke or cerebral ischemia	66.737	10	15
Renal failure	44.491	7	10
Chronic liver diseases and/or cirrhosis	22.246	3	5

Table 9: Data analysis ISAT 2019 - Estimated population with chronic conditions (non-institutionalized)

The population data from ISTAT (Italian National Institute of Statistics) as of January 1, 2021				
Localities	**Age groups**			
	65-74	**75-84**	**≥ 85**	**Totale**
Italia	6.915.504	4.825.173	2.200.854	**13.941.531**
Piemonte	534.834	396.698	180.755	**1.112.287**
Alagna Valsesia	83	64	21	**168**
Moncucco Torinese	131	88	28	**247**

Table 10: Total ISTAT population of elderly individuals (aged > 65 years) with chronic diseases - Italy, Piedmont, Alagna, Moncucco Torinese

In order to obtain more precise and accurate data, contacts were made with some primary care physicians (specifically, those operating in the municipality of Moncucco Torinese) and with the Local Health Authority (ASL) of Vercelli (the reference ASL for another partnering municipality in the FragMont Project, Alagna Valsesia). A series of meetings were organized with the ASL, during which the FragMont Project was presented, and anonymous data on the number of residents with chronic illnesses in the municipality of Alagna Valsesia were requested. To facilitate this, a formal agreement is being developed between the ASL and the Department of Management of the University of Turin, which is still in the process of being finalized.

From the analysis of the obtained data, in addition to those reported in the tables, other disabling chronic conditions such as arthritis/arthrosis and osteoporosis also emerge. These conditions primarily affect older women but appear to be less amenable to remote management through telemonitoring and transmission of biological parameters. In their case, parameters such as pain, functional limitations, and other external signs such as signs of inflammation need to be periodically evaluated. Therefore, other services such as telemedicine visits or telehealth cooperation may be more appropriate.

In this context, an approach that integrates traditional care and assistance with modern telemedicine seems promising (or at least worthy of further investigation). The guidelines of the Italian Ministry of Health (2014) specify that telemedicine can have various purposes, some of which, it seems to the writer, may be relevant to the issues we have previously mentioned:

1. Secondary prevention: These are services dedicated to individuals already classified as at risk or those already affected by diseases who, despite leading a normal life, need constant monitoring of certain vital parameters in order to reduce the risk of complications.
2. Diagnosis: These services aim to transmit diagnostic information rather than the patient. A complete diagnostic process is difficult to perform solely through the use of telemedicine tools, but telemedicine can complement or provide useful insights to the diagnostic and treatment process.
3. Monitoring: The ongoing evolution of demographic dynamics and the resulting changes in the health needs of the population, with an increasing proportion of elderly individuals and chronic diseases, require a structural and organizational redesign of the service network, especially with a focus on strengthening the territorial scope of care. Based on this approach, the FragMont Project is structured, and more specifically, the literature review conducted by the undersigned in the initial months of work to understand the state of the art at a national and international level and, consequently, the possible practical implications.

Figure 19: E-health network monitoring system. Image automatically generated by Bing AI

Following the literature review on telemedicine/telemonitoring applications and solutions, with particular reference to those developed in response to the healthcare and treatment needs of populations residing in remote areas, some necessary and preliminary clarifications are required:

1. Most of the trials and observational studies refer to contexts that are very different from the one examined by our research group. The variability and unique characteristics of each context should be carefully evaluated before proceeding with generalizations that would otherwise be inappropriate.
2. As specified in the telemedicine guidelines developed by the Ministry of Health (2014), the purposes of telemedicine can be different or complementary to each other and may include, depending on the case, services for secondary prevention, diagnosis, monitoring, treatment, and rehabilitation. For our research, the primary focus is likely on

the first three. The same document classifies telemedicine services based on the healthcare professionals involved and the role they, together with the patient, play in the healthcare and treatment relationship. Below is a useful summary.

6.2 Relevant biometric parameters for major pathologies

Mountain communities often face unique challenges that contribute to their vulnerability. These challenges include limited access to essential services and resources, inadequate infrastructure, socioeconomic disparities, and restricted economic opportunities. The isolation and rugged terrain of mountain areas make it difficult to provide timely assistance and access to healthcare, exacerbating the vulnerability of the population, especially for those with pre-existing health conditions or limited mobility.

In mountain areas of Europe, the most frequent diseases among the vulnerable human population can vary depending on various factors such as geographical location, climate, socioeconomic conditions, and access to healthcare. However, several health issues are commonly observed in mountainous regions, some of which are briefly discussed in the following sections.

- **Respiratory Diseases**
  Respiratory diseases, particularly chronic obstructive pulmonary disease (COPD), asthma, and bronchitis, are often more prevalent in mountainous areas. Factors such as high altitude, lower oxygen levels, exposure to air pollution (including indoor air pollution from traditional heating methods), and harsh climatic conditions contribute to respiratory health challenges. These conditions can be particularly problematic for vulnerable individuals, including the elderly and those with pre-existing respiratory conditions.
- **Cardiovascular Diseases**
  Mountain regions are associated with an increased risk of cardiovascular diseases. The combination of high altitude, cold temperatures, and lower oxygen levels can strain the cardiovascular system, leading to conditions such as hypertension, ischemic heart disease, and heart failure. Limited healthcare access and delayed medical interventions in remote mountain areas can further exacerbate the impact of these diseases on the vulnerable population.
- **Mental Health Disorders**
  Isolation, limited social support networks, and challenging living conditions in mountainous regions can have significant impacts on mental health. Depression, anxiety disorders, and seasonal affective disorder (SAD) are more prevalent in mountain communities, especially during long winters with reduced daylight and restricted social interaction. Limited access to mental healthcare services in remote areas can pose additional challenges for those in need.
- **Musculoskeletal Disorders**

The physical demands of living in mountain areas, such as strenuous agricultural work or engaging in outdoor activities, can contribute to musculoskeletal disorders. These include conditions like back pain, arthritis, and joint problems. The rugged terrain, uneven surfaces, and physically demanding occupations increase the risk of injuries and chronic conditions related to the musculoskeletal system.

- **Vector-Borne Diseases**
  Certain mountainous regions may be susceptible to vector-borne diseases such as Lyme disease, tick-borne encephalitis, and mosquito-borne diseases like West Nile virus. These diseases can pose a risk to both residents and tourists in mountain areas, particularly during warmer seasons when vectors are more active. Limited awareness, healthcare infrastructure, and preventive measures can increase the vulnerability to these diseases.

It is important to note that the specific prevalence of diseases may vary among different mountain regions in Europe. Local healthcare authorities and research institutions often conduct studies and surveillance programs to monitor the prevalence and incidence of diseases in specific mountainous areas. Such data can provide more precise insights into the health challenges faced by the vulnerable population and help guide targeted interventions and healthcare services.

Clinical condition/chronic pathology	Parameters susceptible to Home telemonitoring	Minimal reference bibliography
Hypertension	BP (measurement to be performed on the brachial artery/upper arm)	2018 ESC/ESH Guidelines for the management of arterial hypertension: The Task Force for the management of arterialmhypertension of the European Society of Cardiology (ESC) and the European Society of Hypertension (ESH) https://doi.org/10.1093/eurheartj/ehy339
Heart failure / Other cardiac pathologies	- BP (measurement to be performed on the brachial artery/upper arm - HR - SpO2 - Body weight - Other parameters to consider: - ECG parameters - Sleep quality - Steps/24 h - Fluid intake 24 h - Diuresis/24 h - Pain	2021 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure: Developed by the Task Force for the diagnosis and treatment of acute and chronic heart failure of the European Society of Cardiology (ESC) With the special contribution of the Heart Failure Association (HFA) of the ESC https://doi.org/10.1093/eurheartj/ehz486 2021 ESC Guidelines on cardiovascular disease prevention in clinical practice: Developed by the Task Force for cardiovascular disease prevention in clinical practice with representatives of the European Society of Cardiology and 12 medical societies with the special contribution of the European Association of Preventive Cardiology (EAPC). https://doi.org/10.1093/eurheartj/ehab484

Cancer	- BP (measurement to be performed on the brachial artery/upper arm) - HR - SpO2 - Pain - CT scan Body - weight + abdominal circumference - Steps per 24 hours	Linee guida "Tumori dell'anziano" dell'Associazione Italiana Oncologia Medica (AIOM) - 2019 https://snlg.iss.it/wp-content/uploads/2020/09/LG-283-Tumori-Anziano.pdf
Diabetes	- HbA1c - Blood glucose - BP (measurement to be performed on the brachial artery/upper arm) - Body weight - Abdominal circumference (correlated with visceral obesity; in older adults, a better indicator than BMI for underestimating malnutrition/malnourishment) - Other parameters to consider: - HR - SpO2 - Steps per 24 hours - Comprehensive nutritional assessment (using the Mini-Nutritional Assessment) - Insulin units (self-administered subcutaneously)	2019 ESC Guidelines on diabetes, pre-diabetes, and cardiovascular diseases developed in collaboration with the EASD: The Task Force for diabetes, pre-diabetes, and cardiovascular diseases of the European Society of Cardiology (ESC) and the European Association for the Study of Diabetes (EASD) https://doi.org/10.1093/eurheartj/ehz486 See"Effects of intensified glucose control" (pag. 280). Linea Guida della Società Italiana di Diabetologia (SID) e dell'Associazione dei Medici Diabetologi (AMD) - La terapia del diabete mellito di tipo 2 – 2021. https://snlg.iss.it/wpcontent/uploads/2021/07/LG_379_diabete_2.pdf See "Obiettivi terapeutici" (pag. 30), "Esercizio fisico" (pag. 22), "Terapia educazionale" (pag. 23) e "Controllo glicemico" (pag. 29). Standard italiani per la cura del diabete mellito della Società Italiana di Diabetologia (SID) e dell'Associazione dei Medici Diabetologi (AMD) - 2018 https://www.siditalia.it/pdf/Standard%20di%20Cura%20AMD%20-%20SID%202018_protetto2.pdf

Chronic respiratory diseases (in particular COPD)	- SpO2 - Spirometric values (e.g., FEV1, FVC, etc.) - Respiratory rate - Physical activity assessment (shuttle walk test, 6-minute walk test, steps per 24 hours) - Sleep quality - Body weight + abdominal circumference to assess the risk of malnutrition - CT scan - Dyspnea assessment [modified British Medical Research Council (mMRC) questionnaire] - Global symptom assessment [COPD Assessment Test (CAT™)] - Fluid balance monitoring - Other parameters to consider: - Consciousness level - BP - HR - Thoraco-pulmonary impedance (via Forced Oscillation Technique) ECG	[6B] "Among the parameters monitored, only oxygen saturation could timely identify COPD exacerbations. This reflects the expected high specificity of O2 desaturation: it is very unlikely that a condition other than respiratory exacerbation accounts for this event. However, minor differences in the precritical multiparametric profiles were evident". [6C] Vedi "Table 1. Main characteristics and description of the technology used in the studies.". "The most common parameters collected were symptoms (n = 9), oxygen saturation (n = 8), spirometric parameters (n = 6), medication (n = 6), heart rate (n = 5), temperature (n = 3) and weight (n = 3)". [6F] "The forced oscillation technique (FOT) measures the mechanical properties of the lung during tidal breathing in a way that is simple to perform without supervision or effort, is operator independent, and can be undertaken at home by patients with COPD. FOT can also detect changes in lung mechanics acutely after a bronchodilator and during recovery from an exacerbation, making it a potentially attractive way to objectively define exacerbation events in a telemonitoring program". Nevertheless "in older patients with COPD and comorbidities, remote monitoring of lung function by forced oscillation technique and cardiac parameters did not change TTFH (time to first hospitalization) and EQ-5D (EuroQoL EQ-5D utility index score)." GOLD pocket guide 2021. Strategia globale per la diagnosi, il trattamento e la prevenzione della BPCO (Revisione 2021) https://goldcopd.it/wp-content/uploads/materiali/2021/GOLD_Pocket_2021.pdf [vedi approfondimento sotto tabella] Fondazione GIMBE - Linee guida per la diagnosi e la terapia della broncopneumopatia cronica ostruttiva negli adulti (2019) https://snlg.iss.it/wp-content/uploads/2019/12/BPCO-negliadulti. Pdf ** [vedi approfondimento sotto tabella] NICE guideline - [NG115] Chronic obstructive pulmonary disease in over 16s: diagnosis and management (Published: 05 December 2018 Last updated: 26 July 2019) https://www.nice.org.uk/guidance/ng115/chapter/Recommendations#managing-stable-copd

- **Stroke or cerebral ischemia**	- BP (measurement to be performed on the brachial artery/upper arm) - HR - Blood glucose levels (in diabetic patients) - Sleep quality - Steps per 24 hours - Other parameters to consider: - SpO2 - Body weight + abdominal circumference - ECG parameters	ESO (European Stroke Organisation) Guidelines Directory https://eso-stroke.org/guidelines/eso-guideline-directory/ 2021 Guideline for the Prevention of Stroke in Patients With Stroke and Transient Ischemic Attack: A Guideline From the American Heart Association/American Stroke Association https://doi.org/10.1161/STR.0000000000000375 WHO/OMS Guidelines for Management of Stroke - 2012 https://extranet.who.int/ncdccs/Data/MNG_D1_1.%20Clinical%20guideline%20of%20Acute%20Stroke%20.pdf
Kidney failure	- BP (measurement to be performed on the brachial artery/upper arm) - Body weight + abdominal circumference - Steps per 24 hours - Blood glucose levels (in diabetic patients)	ISS-SNLG. Identificazione, prevenzione e gestione della malattia renale cronica nell'adulto. 2015 https://www.salute.gov.it/portale/news/p3_2_1_1_1.jsp?menu=notizie&id=649 Vaidya, S. R., & Aeddula, N. R. (2021). Chronic Renal Failure. In StatPearls. StatPearls Publishing.

Chronic liver diseases and/or cirrhosis	- Body weight + abdominal circumference - Heart rate variability (measured through ECG) - RR interval (measured through ECG) - Level of consciousness: apathy, lethargy, semi-unconsciousness (indicator of overt hepatic encephalopathy) - Temporal orientation (indicator of overt hepatic encephalopathy) - BP (measurement to be performed on the brachial artery/upper arm) - HR Blood glucose levels (in diabetic patients) - Comprehensive nutritional assessment - Other parameters to consider: - SpO2 Motor assessment (including evaluation of gait and walking, considering the risk of falls)	American Association for the Study of Liver Diseases, & European Association for the Study of the Liver (2014). Hepatic encephalopathy in chronic liver disease: 2014 practice guideline by the European Association for the Study of the Liver and the American Association for the Study of Liver Diseases. Journal of hepatology, 61(3), 642–659. https://doi.org/10.1016/j.jhep.2014.05.042 Montagnese, S., Russo, F. P., Amodio, P., Burra, P., Gasbarrini, A., Loguercio, C., Marchesini, G., Merli, M., Ponziani, F. R., Riggio, O., & Scarpignato, C. (2019). Hepatic encephalopathy 2018: A clinical practice guideline by the Italian Association for the Study of the Liver (AISF). Digestive and liver disease: official journal of the Italian Society of Gastroenterology and the Italian Association for the Study of the Liver, 51 Stotts, M. J., Grischkan, J. A., & Khungar, V. (2019). Improving cirrhosis care: The potential for telemedicine and mobile health technologies. World journal of gastroenterology, 25(29), 3849–3856. https://doi.org/10.3748/wjg.v25.i29.3849 Garcia-Pagan, J. C., Francoz, C., Montagnese, S., Senzolo, M., & Mookerjee, R. P. (2021). Management of the major complications of cirrhosis: Beyond guidelines. Journal of hepatology, 75 Suppl 1, S135–S146. https://doi.org/10.1016/j.jhep.2021.01.027

Table 11: Health parameters for telemedicine

(Note: The specific details of the classification mentioned in the text are not provided, but it refers to a summary that follows in the subsequent text.)

Vital Parameters: BP (blood pressure), HR (heart rate), SpO2 (peripheral oxygen saturation, an indicator of oxygen saturation in arterial blood), RR (respiratory rate), BT (body temperature), Level of consciousness, Pain.

Other parameters: Skin color, condition and integrity, Blood glucose level, Body weight, Urine output (usually measured as urine output per 24 hours), Spirometry values (e.g., pulmonary impedance), Steps (an index of physical activity performed in 24 hours), BMI [weight in kg / (height in meters)2], Waist circumference (correlated with visceral obesity), etc.

(*) ”Pulse oximetry and arterial blood gas analysis.
Pulse oximetry can be used to assess the arterial oxygen saturation of the patient and the need for oxygen therapy. Pulse oximetry should be used to evaluate all patients with clinical signs suggestive of respiratory failure or right heart failure. “If peripheral saturation is less than 92%, arterial or capillary blood gas analysis should be performed." "Reduced exercise tolerance objectively measured, evaluated through the reduction in self-paced walk distance

or during an incremental exercise test in the laboratory, is a powerful indicator of compromised health status and a predictor of prognosis. [...] Walk tests are useful for assessing disability and mortality risk, and are used to verify the effectiveness of respiratory rehabilitation."

Diagnosis, classification of airway obstruction severity: spirometry values (FEV1/FVC, FEV1), evaluation of dyspnea (mMRC), assessment of symptoms (CAT™).
Non-pharmacological treatment of stable COPD: (among other things) ensuring the maintenance (and, where possible, promoting the increase) of physical activity and exercise programs, adequate nocturnal rest, and a balanced diet (considering nutritional supplementation in malnourished patients with COPD); self-management education and guidance from healthcare professionals should be fundamental components of the "Chronic Care Model"; monitoring/managing worsening of symptoms (dyspnea, etc.); finally, regarding the prescription and evaluation of long-term oxygen therapy, certain blood gas values and SpO2 are crucial.
Monitoring and follow-up: monitor spirometry values, dyspnea, symptoms, SpO2, and the other indicators/parameters described above. In particular, following discharge from hospitalization, ensure a management plan for comorbidities and follow-up; subsequently (at 1-4 weeks and 12-16 weeks from diagnosis/severity classification), determine the status of any comorbidities.
Management of exacerbations: exacerbations are mainly triggered by viral respiratory infections, although bacterial infections and environmental factors such as pollution and ambient temperatures can also initiate and/or amplify these events (monitor signs/symptoms of infection, e.g., body temperature).
Management of severe, but non-life-threatening exacerbations: always monitor fluid intake.
In summary, some of the most useful values/investigation tools are: SpO2, respiratory rate, spirometry values, body temperature; chest X-ray and blood gas analysis, on the other hand, are not manageable at home by patients but can be performed in an outpatient clinic or medical center.
Note: "According to current literature, complete self-management or routine check-ups have not shown long-term benefits in terms of health status compared to the usual standard of care for patients with COPD."

(**) This article summarizes the most recent recommendations (2018, see below) from the National Institute for Health and Care Excellence (NICE). Diagnosis: FEV1/FVC, symptoms, and signs.

* Prognostic factors:
  - FEV1
  - Dyspnea (MRC scale)
  - Chronic hypoxia and/or pulmonary heart disease
  - Low BMI value

- Severity and frequency of exacerbations
- Hospitalizations
- Severity of symptoms (e.g., CAT score)
- Exercise capacity (e.g., 6-minute walk test)
- Carbon monoxide diffusing capacity test (TLCO or DCO test)
- Presence of criteria for long-term oxygen therapy and/or home non-invasive ventilation
- Multimorbidity
- Frailty

Telemedicine monitoring of COPD: In the management of stable COPD patients, do not routinely prescribe telemedicine monitoring of physiological parameters as it does not improve quality of life, does not reduce hospitalizations, and increases costs [Recommendation based on evidence of varying quality from controlled randomized trials and directly applicable health economics evidence].

7. Telemedicine and Guidelines

For over a decade, the European Commission has placed particular emphasis on the topic of telemedicine. In the European Communication (COM-2008-689) "Telemedicine for the benefit of patients, healthcare systems, and society" dated November 4, 2008, a series of actions were identified involving all levels of government, both at the community level and within individual Member States, to promote greater integration of telemedicine services in clinical practice by removing the main barriers that hinder its full and effective implementation. Telemedicine highlights the importance of considering the digital divide and limited connectivity in mountain regions and the need for tailored approaches to ensure equitable access to telemedicine solutions.

7.1 The National Health Council approves national guidelines

In order to systematically implement telemedicine within the National Health Service and to implement the European Communication, the Technical Committee on Telemedicine was established at the National Health Council (CSS). This committee developed specific national guidelines to:

- Identify priority areas for the application of telemedicine.
- Analyze models, processes, and methods of integrating telemedicine services into clinical practice.
- Define common taxonomies and classifications.
- Address regulatory and legislative aspects, as well as the economic sustainability of telemedicine services and provisions.

The first set of national guidelines on Telemedicine was approved by the General Assembly of the National Health Council on July 10, 2012.

7.2 From Guidelines to National Recommendations

Following the State-Regions Agreement of February 20, 2014, and the Reports of the Higher Institute of Health COVID-19 No. 12/2020 "Interim Guidelines for Telemedicine Assistance Services during the COVID-19 Health Emergency" of April 13, 2020, and No. 60/2020 "Interim Guidelines for Telemedicine Healthcare Services in Pediatrics during and beyond the COVID-19 pandemic" of October 10, 2020, during the meeting of the National Health Service (NSIS) Steering Committee on July 28, 2020, the Ministry of Health and the Regions and Autonomous Provinces of Trento and Bolzano shared the need to provide uniform guidelines throughout the national territory for the delivery of remote healthcare services, with particular emphasis on specialist activities, extending medical and healthcare practices beyond the physical spaces where they traditionally take place according to traditional procedures, also in relation to initiatives launched by some regions during the COVID-19 emergency period.

The Telemedicine Working Group, which also included experts and representatives of the national federations of healthcare professions (FNOMCeO and FNOPI), therefore prepared the document "National Recommendations for the Provision of Telemedicine Services," which was approved by the NSIS Steering Committee at its meeting on October 28, 2020, and adopted with an Agreement in the State-Regions Conference on December 17, 2020 (Act Register No. 215/CSR).

This document aims to provide national guidelines for the delivery of certain telemedicine services, such as teleconsultation, telemedical consultation, teleassistance by healthcare professionals, teleinterpretation, so that the use of telemedicine services (e.g., teleconsultation for follow-up visits) becomes a concrete element of organizational innovation in the healthcare process.

7.3 The importance of e-health, telemedicine, and telemonitoring devices in patients with chronic conditions residing in mountain communities

Telemedicine is an integrative mode of healthcare delivery that uses new technologies in situations where the healthcare professional and the patient are in two different locations. It is used to complement traditional healthcare services that involve direct interaction between the doctor and the patient and involves the transmission of medical data necessary to achieve the following objectives:

- **Secondary prevention**, targeting individuals with conditions that need to be monitored over time.
- **Diagnosis**, using telemedicine tools to obtain diagnostic information without requiring the patient to travel.
- **Treatment**, making therapeutic decisions when the diagnostic picture is already clear.
- **Rehabilitation**, providing rehabilitation interventions at the patient's home or another healthcare facility.
- **Monitoring**, managing the patient over time through data exchange between the patient and the personnel responsible for interpreting them.

Telemedicine includes within its scope:

- **Specialist telemedicine**, including teleconsultation (which involves remote consultation between doctors and does not require the presence of the patient, even remotely) and teleconsultation, which consists of remote consultation activities between doctors and does not involve the presence of the patient.

- **Telehealth**, which is primarily applied to chronic patients and encompasses all systems that allow them to be remotely assisted in the stages of diagnosis, monitoring, and disease management. It enables the healthcare professional to take charge of the patient, not only monitoring the situation (telemonitoring) but also supporting them in therapy management.
- **Teleassistance**, which pertains to the social and healthcare field and involves taking care of the patient at their home through remote management, which may include activating 24-hour emergency services, alarm systems, and support calls from the service provider.

Telemedicine has become increasingly essential in managing the rise of chronic diseases. In Italy, there are 24 million people affected by chronic diseases, accounting for almost 40% of the population between 18 and 75 years old. Among them, more than 12 million individuals have multiple chronic conditions, and 1 in 6 requires constant assistance, usually provided by family members at home.

Chronic diseases particularly affect the elderly. Currently, individuals aged 65 and over represent 23.2% of the total population (a percentage that is continuously increasing: it is estimated that by 2050, over 35% of the Italian population will be over 65 years old). More than half of the elderly population suffers from a chronic illness. The most common conditions remain the same as those identified in the 2019 ISTAT survey: osteoarthritis, hypertension and other heart diseases, lumbar and cervical pathologies, and diabetes.

The increase in chronic diseases has led to the need for intensified integrated home care, combined with remote assistance, especially for the most fragile patients.

It is also for this purpose that FragMont was created, a project aimed at elderly patients with one or more conditions requiring clinical monitoring and continuous multidisciplinary care, including healthcare, social, psychological, and assistance services, and who live in mountainous municipalities. This approach allows for addressing the complex needs of frail complex chronic patients, including the use of telemedicine tools for remote monitoring of vital signs and teleconsultation, such as sphygmomanometers, pulse oximeters, electrocardiographs, and glucometers.

In such patients and conditions, telemedicine can be particularly effective because these individuals require constant and timely contact with their primary care physician or specialist. Remote medicine allows for obtaining real-time updated data, continuous analysis, and immediate adjustment of treatments and therapies. In fact, telemedicine is proving to be a valuable tool in managing chronic patients by promoting early diagnosis and personalized interventions that focus on specific individual needs.

It is beneficial for both healthcare professionals and patients, as well as for the government, optimizing healthcare processes and reducing hospitalizations and public costs.

Telemonitoring is also considered an effective tool by caregivers responsible for the care of chronic patients. According to data from a study conducted by the Health Observatory of UniSalute, over 51% of caregivers consider telemonitoring to be a very useful tool in improving the quality of life for patients with irreversible conditions and for the individuals who care for them. However, there is still a significant information gap that limits its dissemination among less educated segments of the population.

Telemedicine does not aim to completely replace or supplant the "traditional" forms of healthcare (also due to certain evident and inevitable structural limitations) that have been established in the healthcare practice over the past decades, but rather to complement them. Particularly, it seeks to overcome logistical and organizational challenges by leveraging new technological tools that enable the movement of information instead of the patient.

The field of chronic conditions is highly complex. Research often focuses on individual diseases or pathological conditions, but in reality, they are often coexisting (referred to as comorbidities), involving 2, 3, or more conditions concurrently present in the same individual. Studies that have enrolled patients with specific chronic diseases may have had a relatively younger average age, excluding a significant portion of older adults who are more affected by comorbidities.

Additional important aspects to consider are patient privacy and the so-called "technological non-compliance" among older individuals, which could potentially interfere with or undermine the effectiveness of certain telemedicine and telemonitoring solutions compared to younger patients.

Therefore, telemedicine applied to the management of chronic patients ensures:

- Constant and timely communication between doctors and patients.
- Overcoming geographical barriers and extended accessibility to specific services and consultations with specialists, regardless of the patient's place of residence.
- The ability for doctors to receive real-time data, reports of anomalies and issues, and promptly intervene by adapting the therapy.
- Improved communication and interoperability among different healthcare professionals and resources.
- Increased patient and caregiver education regarding the specific condition, leading to an improvement in quality of life.

All of these aspects contribute to a significant reduction in severe forms of chronic diseases, a decrease in hospitalizations often caused by non-compliance with prescribed treatments, and a consequent lowering of management costs that burden public expenses.

8. Prototype of a telemedicine system

Building upon the work outlined in the chapter "Investigation on the Frailty of the Population," efforts have been made to develop a telemedicine system that could support an elderly person living in isolation. The system brings value not only in the case of a catastrophic event that hinders access to the elderly person, but also in daily life. By enabling the remote transmission of biometric data, it allows the doctor or nurse to monitor the patient's health status without necessarily having to visit their home. This not only results in cost savings due to reduced travel for the healthcare professional but also saves their time and enables more frequent measurements and readings. In the case of parameters included in the platform, the doctor or nurse will have a continuous overview of the patient's condition, only needing to visit them for treatments, unforeseen check-ups, or to maintain human contact.

The sensor system has been developed in two parts: one that can operate without requiring the active involvement of the patient and monitors the state of the living environment, and another part related to the monitoring of the individual.

In mountain areas, e-health services and telemedicine play a crucial role in addressing the healthcare needs of fragile individuals, including those living alone, those with caregivers, and those living in families. These services leverage the potential of open-source technologies like Raspberry Pi to provide cost-effective and accessible solutions. Monitoring health conditions and pathologies with sensors, tailored e-health services can be developed to meet the unique requirements of individuals in mountain regions.

8.1 Fragile Individuals Living Alone

Fragile individuals living alone in mountain areas often face challenges in accessing healthcare services due to geographical constraints and limited healthcare infrastructure. E-health services can bridge this gap by offering remote monitoring and teleconsultation solutions. For instance, sensors can be deployed to monitor vital signs, such as heart rate, blood pressure, and oxygen levels, which are critical for individuals with cardiovascular diseases or respiratory conditions. Telemedicine systems can collect and transmit this data securely to healthcare providers, enabling timely intervention and personalized care. Remote video consultations can also be facilitated, allowing healthcare professionals to remotely assess patients' conditions and provide medical advice, reducing the need for travel and ensuring continuous care for fragile individuals.

8.2 Fragile Individuals with Caregivers

For fragile individuals in mountain areas who have caregivers, e-health services can enhance caregiving capabilities and improve communication between the caregiver and healthcare providers. Telemedicine solutions can be employed to create remote monitoring systems that allow caregivers to track vital signs, medication adherence, and other health parameters of the individuals they care for. Sensors connected to devices can collect data, and caregivers can access this information through user-friendly interfaces or mobile applications. This real-time data enables caregivers to closely monitor the health status of the individuals they care for and promptly respond to any emergencies or changes in their condition. It also facilitates communication between caregivers and healthcare professionals, who can remotely review the collected data and provide guidance and support as needed.

8.3 Fragile Individuals Living in Families

Fragile individuals living in families in mountain areas can benefit from e-health services that promote family involvement and support. Raspberry Pi-based systems can be used to develop applications and interfaces that allow families to actively participate in the care of their loved ones. For example, sensors can monitor medication adherence, mobility, and other health indicators relevant to specific conditions such as diabetes or limited mobility. This data can be shared with family members, fostering a collaborative approach to healthcare management. Families can receive alerts and reminders related to medication schedules or healthcare appointments, ensuring that the fragile individuals receive the necessary care and support from their family unit. Additionally, teleconsultations can be facilitated to enable family members to participate in medical discussions and treatment planning, creating a more comprehensive and patient-centered care approach.

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Figure 20: Example of health monitoring parameters on fragile individual. Image automatically generated by Bing AI

8.4 The fragile subject in their daily environment

Monitoring the environment in which the elderly person lives allows for the acquisition of information about their health and well-being in a completely automatic manner, without requiring active engagement from the patient as in the case of biometric parameters.

Figure 21 illustrates a possible application of environment monitoring in which the elderly person resides. Examples of the contributions that sensors can provide include detecting gas leaks to improve safety or monitoring temperature and humidity for comfort and well-being. Monitoring the person's movement at home enables sending alerts if the elderly person is not moving at all or suspecting that their health is deteriorating if they are becoming less active, spending more time sitting or in bed. The use of cameras can also detect not only movement but also if the elderly person has fallen and is unable to get up.

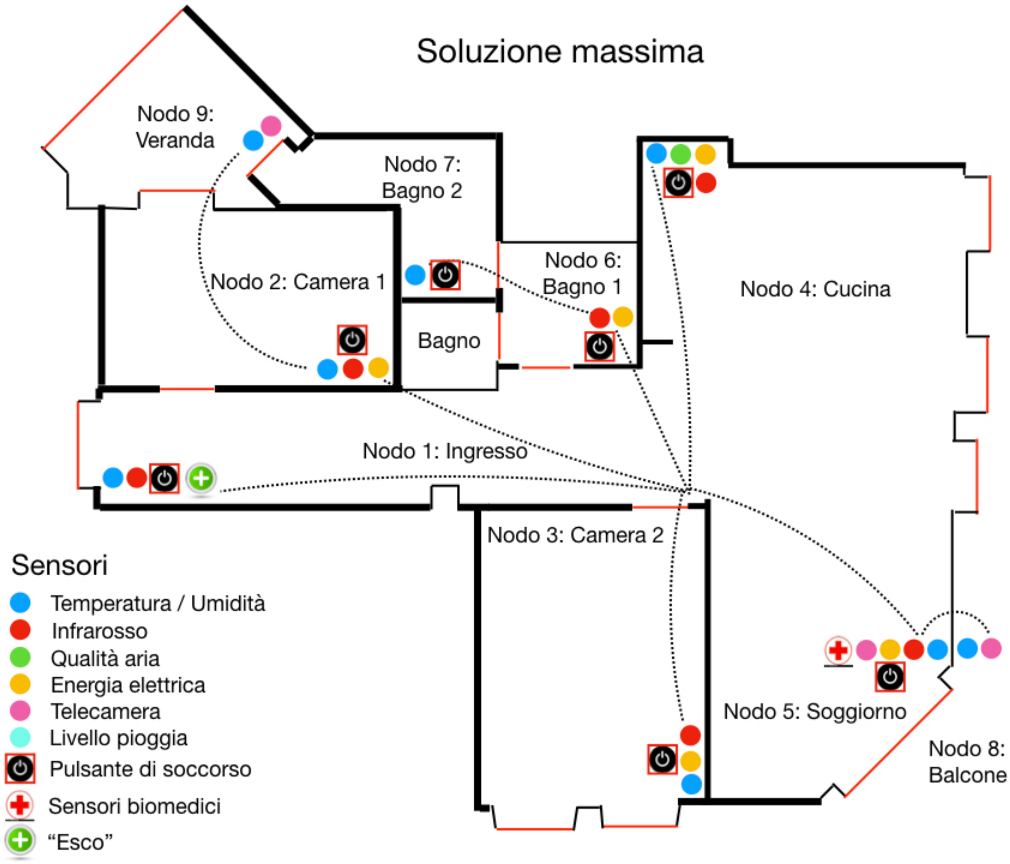

Figure 21: An example of a project for installing sensors to monitor the environment in which an isolated elderly person lives

In the final phase of the FragMont Project, a real sensor network was implemented and installed in the home of a willing participant for testing purposes. The sensors captured various values that were sent to a server and made accessible through the graphical interface shown in Figure 22.

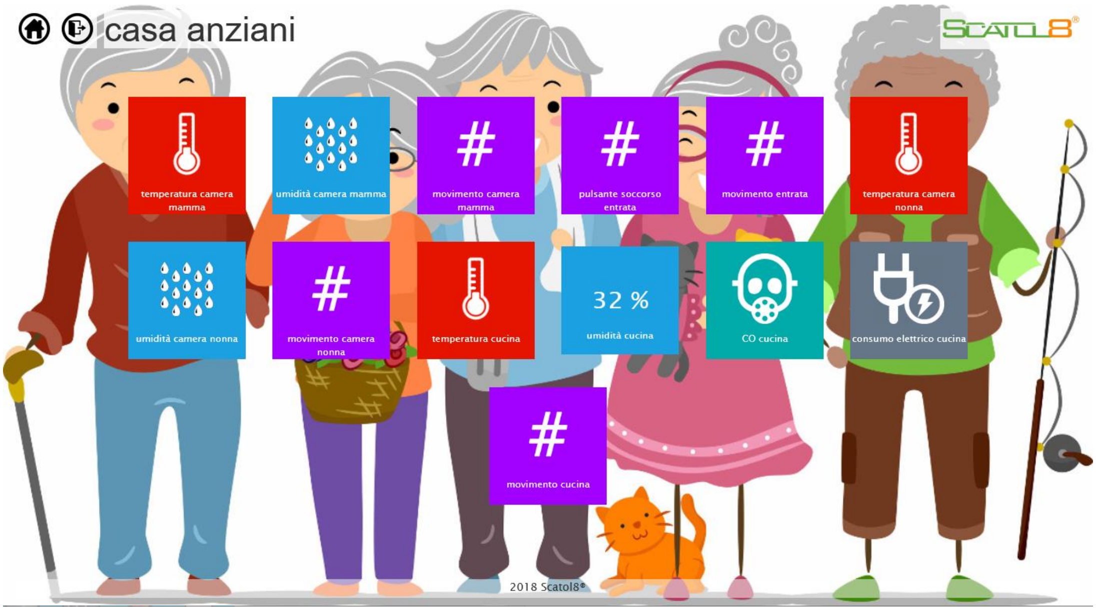

Figure 22: The graphical interface for accessing data from the test network

The tests conducted revealed that, after a few weeks of supervised learning, it was possible to identify recurring patterns in the elderly person's habits, such as getting up or watching television at the same time. Deviations from patterns associated with normal situations can suggest anomalous events.

Analyzing habits and immediate changes in behavior can serve as indicators for family members or the doctor of an abnormal event. For example, the graph in Figure 23 can be obtained by monitoring the power consumption of the television in the kitchen. If the appliance, which is normally used at the same time during lunch and dinner, suddenly remains off, it could indicate a change in habits that may be related to the person's health, interpreting the data together with information from motion sensors inside the home. On the other hand, periodic use during the nighttime can provide insights into a possible state of insomnia in the frail person. Supervised learning allows the detection of data to be linked to the situations that normally occur within the home. The variables' trends can undergo changes depending, for example, on the presence of one or more people who have visited the elderly person on a given day. This circumstance may result in the simultaneous presence, as indicated by the system, in different rooms or a higher frequency of visits to a specific area of the home, without it necessarily being an anomalous situation. Identifying typical situations and connecting them to specific circumstances is useful for the effective learning of the neural network that controls the elderly person's activities in their living environment.

Such a solution has several advantages. Firstly, thanks to the increasing prevalence of artificial intelligence algorithms, the program can autonomously learn what the normal patterns are, and when an anomalous situation occurs, it can send an alert. Compared to a camera, sensors like the power consumption sensor are also less invasive in terms of violating the privacy of the elderly person.

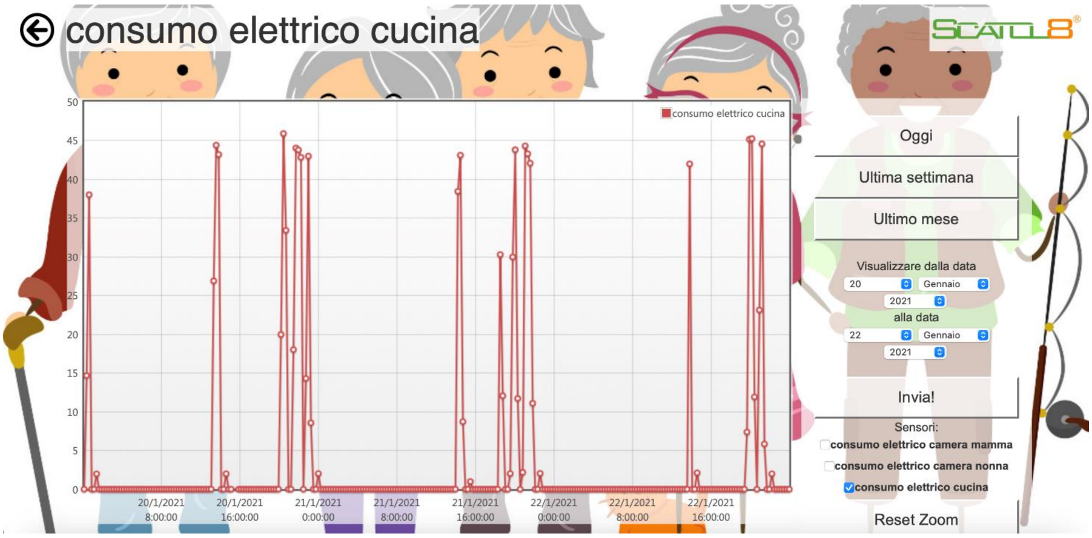

Figure 23: The trend of electricity consumption can also provide insights into the habits of the elderly person

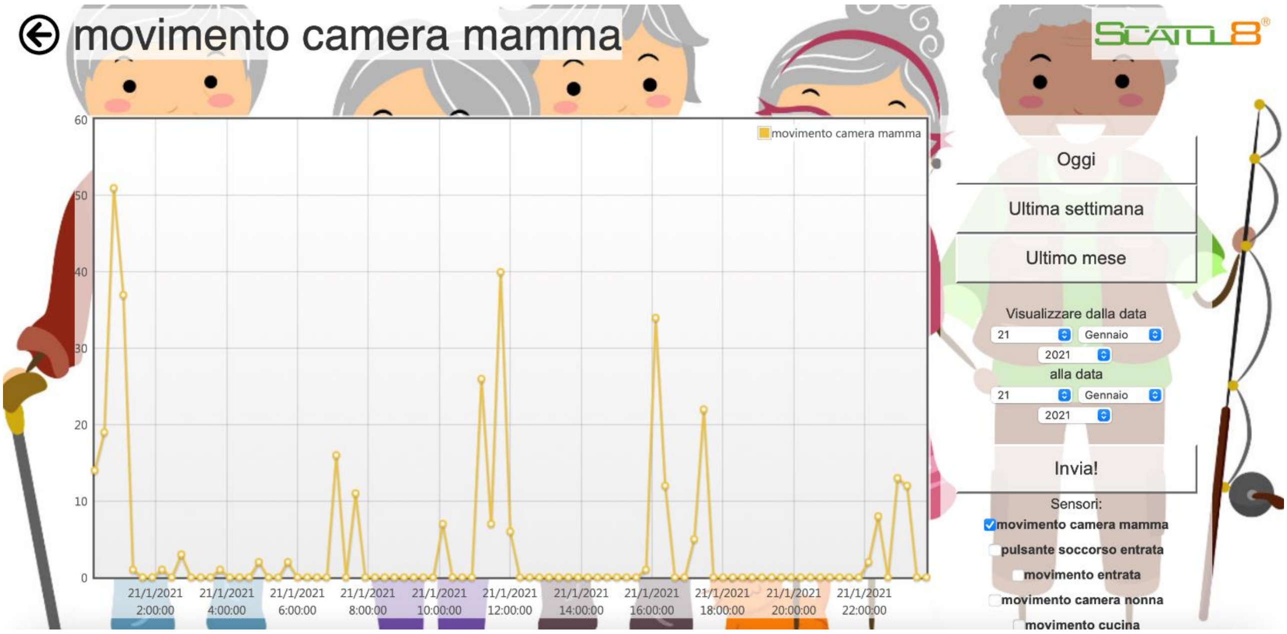

Figure 24: An example of a chart showing the movements detected by a motion sensor

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The use of motion sensors, such as infrared sensors used in burglar alarms, allows us to obtain indications of habitual behaviors to infer the elderly person's health status with a low cost and a particularly robust system. In this case as well, normal or anomalous situations can be identified, perhaps with reference to nocturnal movements, which are then traced through movements from the bedroom to the entrance of the apartment and the kitchen. When evaluating the data in this case, other external factors should be taken into account, if present, such as the presence of a caregiver or a visiting relative at a specific time.

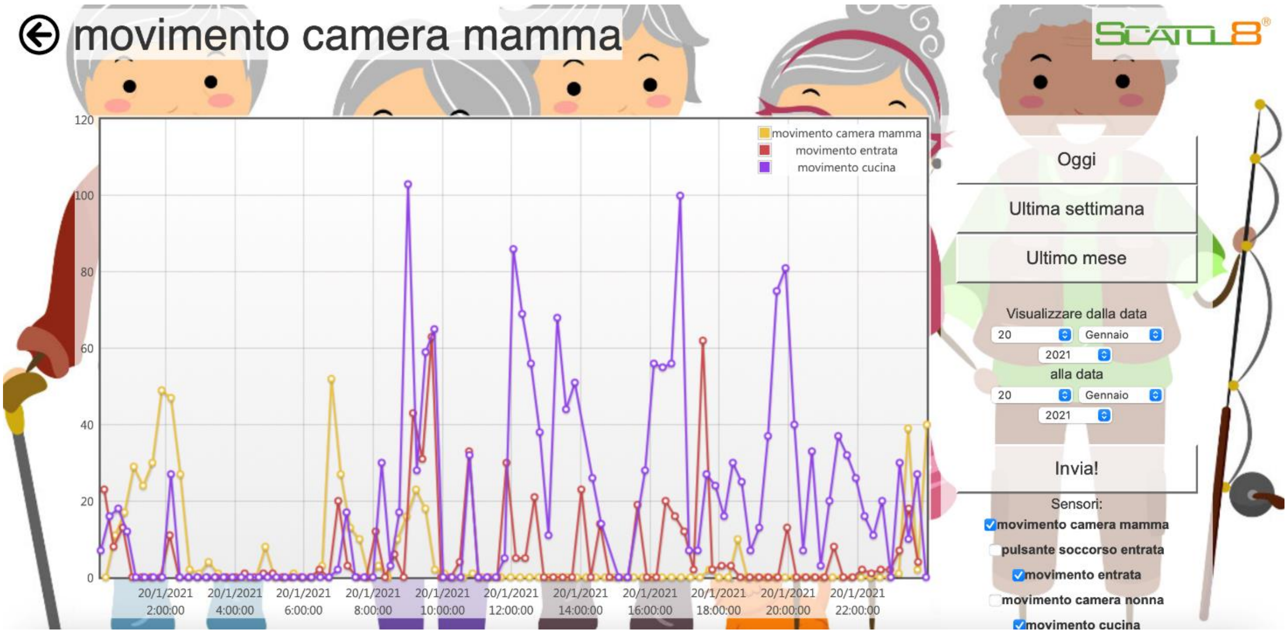

Figure 25: The monitoring system allows for comparing values related to the same parameter. In this case, the comparison is made on the person's movements in various domestic environments

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Remote monitoring of the individual is the tool that allows for cost reduction, increased frequency of biometric parameter checks, and monitoring of the person's health status even when they are unreachable by healthcare professionals due to a catastrophic event.

Once the Project identified the most relevant parameters in the areas considered, as explained in Chapter 6, it focused on identifying existing solutions and developing a prototype. Having a prototype is important in the project context as it allows verifying its usability for the elderly on one hand and its usefulness for doctors and family members on the other.

8.5 Researching existing solutions on the market

Researching existing solutions on the market was the first phase of the work. The ideal system should meet several requirements. First and foremost, the platform should include the maximum number of selected sensors based on the criteria outlined in the chapter 6.

Additionally, the user experience should be intuitive, allowing individuals with reduced vision, dexterity, and technology literacy to use it. The system should also have the capability to share data by sending it to a remote server since, for the purposes of the Project, on-site consultation alone is not acceptable.

Name	Website	Features	Considerations
Bewell Connect	http://www.aditechsrl.it/healthcare/salute-connessa/bewellconnect	A mobile app for smartphones with proprietary sensors. It includes a thermometer, pulse oximeter, blood pressure monitor, scale, and electrocardiograph.	The collected data can be shared by manually exporting them to PDF. However, the interface is not suitable for elderly users.
Libelium e-Health Sensor platform	https://www.cooking-hacks.com/documentation/tutorials/ehealth-biometric-sensor-platform-arduino-raspberry-pi-medical.html	It is not a finished product but a highly customizable hardware prototyping platform. It includes sensors such as heart rate, blood oxygen level, body temperature, blood pressure, fall detection, respiration, ECG, and galvanic skin response.	Some sensors, such as the heart rate sensor, may occasionally produce inaccurate results. In general, it would be an excellent starting point, but unfortunately, the system is no longer in production.
Omron connect	https://www.omron-healthcare.it/it/omronconnect.html	Sensors can be paired via Bluetooth with the mobile application. The measurable values include temperature, body weight, blood pressure, heart rate, and blood oxygen saturation.	The platform works well, but the fact that it is closed does not allow for direct forwarding of the data to a doctor. Additionally, the interface is not easily accessible for elderly users.
iHealth	https://ihealthlabs.eu/it/	Sensors can be paired via Bluetooth with the mobile application. The measurable values include temperature, blood glucose level, body weight, blood pressure, heart rate, and blood oxygen saturation.	The platform works well, but the fact that it is closed does not allow for direct forwarding of the data to a doctor. Additionally, the interface is not easily accessible for elderly users.
Beurer	https://www.beurer.com/web/it/prodotti/medical/prodotti-in-rete.php	Sensors can be paired via Bluetooth with the mobile application. The measurable values include temperature, body weight, fertility, heart rate, blood pressure, and blood oxygen saturation.	The platform works well, but the fact that it is closed does not allow for direct forwarding of the data to a doctor. Additionally, the interface is not easily accessible for elderly users.

Viatom	https://www.viatomtech.com/remote-solution	The device sends data to the internet without the elderly person needing to use an app. Blood oxygen level, pulse rate, and perfusion index can be measured with the remote linker. Temperature, ECG, and blood pressure can be measured using the phone application.	The "remote linker" is specifically designed to forward the data to a doctor or a relative.

Table 12: Ready-to-use solutions for monitoring biometric parameters illustrate some of the solutions found on the market

Almost all solutions available on the market allow for the measurement of certain biometric parameters and transmit the values via Bluetooth to an app on an Android or iOS phone, which then typically forwards the data to the manufacturer's proprietary server. Unfortunately, mobile apps do not have a user interface suitable for elderly individuals who are not familiar with technology, and in the case of some tested devices, the pairing between the measurement device and the app proved to be cumbersome even for technologically savvy users.

Two solutions that stand out are those from Viatom and Libelium. The first solution involves a device called a "remote linker," which serves as a Bluetooth-WiFi converter, allowing the forwarding of values measured by a pulse oximeter to the internet. In this case, the solution is easily usable by an elderly individual without requiring a mobile app. Unfortunately, at present, all other Viatom sensors cannot be used with the remote linker and instead require a mobile application.

The Libelium solution, on the other hand, consists of a prototyping platform that provides sensors and software libraries, leaving the development of the user interface to the buyer's flexibility.

In addition to biometric parameter detection systems, the market offers various other systems that can contribute to the safety of the elderly, such as buttons for sending alarms in case of distress (MobileHelp, 2023) or automatic fall detection systems (Vebiro S.R.L.C.R, 2023).

8.6 Development of the prototype

Given that a single product with all the desired characteristics could not be found on the market, a part of the Project focused on developing a prototype by integrating various sensors with a single application designed for an elderly person's user experience.

The work progressed through the following phases:

- Research on interfacing sensors.
- Sensor interfacing using a microcontroller or Bluetooth.
- Development of an application suitable for use by an elderly individual.
- Test backend for remote data collection.

The research phase for the sensors focused on the biometric parameters identified in section 6.2, namely weight, blood pressure, heart rate, blood oxygen level, temperature, and blood glucose level.

The starting point for developing the prototype was the Libelium e-health platform mentioned in the previous sections. Specifically, the system consists of an electronic board compatible with the widely used Arduino prototyping platform, which expands its capabilities by allowing the connection of various biometric sensors (figure 26).

Figure 26: The Libelium e-health prototyping platform with a connected pulse oximeter

We conducted numerous tests on the platform, considering it particularly suitable for our purposes. However, the results of the tests were not entirely positive for various reasons. Regarding heart rate and oxygen saturation, we obtained readings that were not always accurate. The technical reason behind this is that the data is read by intercepting the signals going to the seven-segment display of the pulse oximeter. The data is read with a fixed timing, while the values take different times to be written on the display based on the number of segments that need to be illuminated to compose the detected value.

As for blood pressure, correct values were obtained, but the device chosen by Libelium, the KODEA KD-202F, requires a rather complicated user interaction to send and delete data from its memory, making it less usable in general and particularly for an elderly person. Additionally, the Libelium solution was discarded because the manufacturer has removed it from the market.

However, the Arduino prototyping platform proved to be an excellent tool for interfacing with wired sensors and a computer that can be used for the prototype's user interface. For example, for body temperature, we used a DS18b20 sensor connected to a microcontroller that reads the temperature and sends the data to a computer via a USB connection.

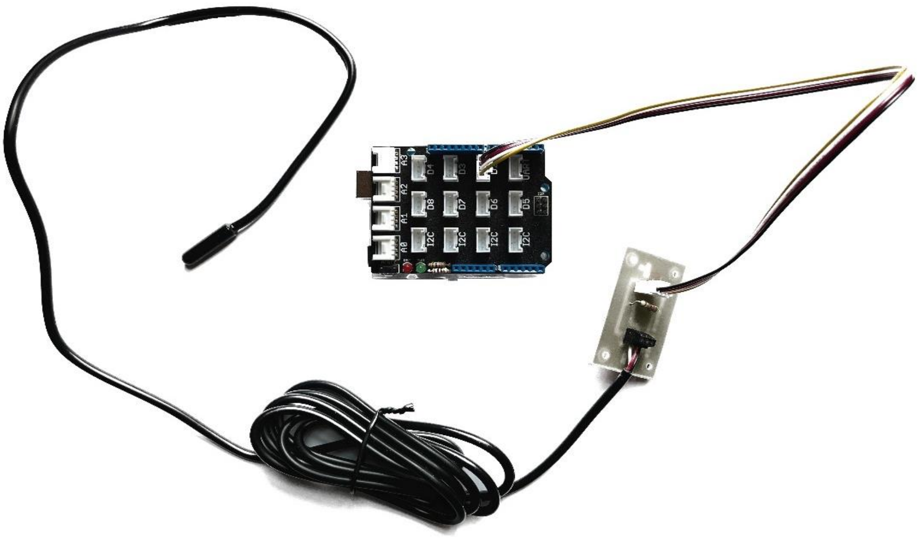

Figure 27: The body temperature sensor connected to the Arduino prototyping platform

In the search for sensors, we prioritized choices with wired interfaces because they have two main advantages: they do not require replacing or recharging a battery on the sensor, and they may not require any interaction with the sensor itself other than with the application on the totem system. However, we were unable to find suitable wired sensors for weight, blood pressure, blood oxygen, pulse, and glucose. Therefore, we proceeded to purchase the Bluetooth solutions listed in Table 12, which are currently being tested.

Variable	Sensor
Weight	OMRON VIVA
Weight	iHealth Fit
Blood pressure	OMRON M4
Blood pressure	iHealth track
Heart rate and blood oxygen level	OMRON P300 IT
Heart rate and blood oxygen level	iHealth Air
Blood glucose	iHealth BG5

Table 13: Bluetooth sensors currently in testing

In parallel with the sensor research, the Project included the development of an application that would allow the elderly person to perform measurements in the simplest way possible. Figure 28 shows the main screen where the selection of the variable to be measured is made. The buttons are organized to occupy one-sixth of the entire screen, making it easier to read the text, recognize the icons, and press them..

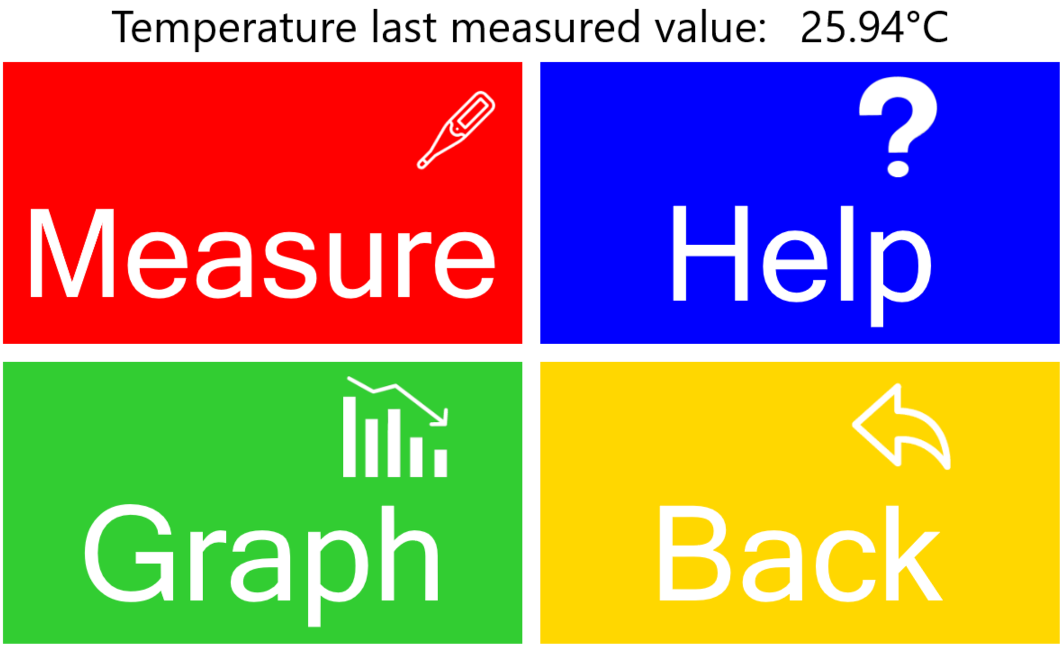

Figure 28: The main screen of the application for monitoring biometric parameters

Later, you will access the screen shown in Figure 29, which corresponds to the individual sensor and allows you to take a new measurement by pressing the corresponding button,

Figure 29: The screen for measuring and viewing the values of an individual sensor

instead of consulting the list of recorded values or returning to the main page to choose different sensors.

Once the measurement operation is completed, the application immediately displays the acquired value on the screen and provides access to a list of various recordings.

However, as mentioned earlier, the utility of the tool is not limited to being a simple local data recorder but involves sending the measurements remotely to share them with a doctor, nurse, or family members. In this design phase, issues related to data ownership and sharing were not considered because the objective is to test the actual ease of use of the tool by the elderly and its real usefulness for healthcare professionals.

The data is sent from the computer, where the user interface is running, typically via Wi-Fi or Ethernet connection. Since the application is a Windows app, the Project remains independent of the data transmission system, which, considering the mountainous context, could be different from the ones mentioned above, using cellular network connections, WIMAX, satellite, etc.

The data travels through the internet and reaches the backend, which has been developed using HTML, PHP, JavaScript, and SQL. The backend allows for storing the information in a MySQL database and provides a graphical interface to query the data, as shown in Figure 30.

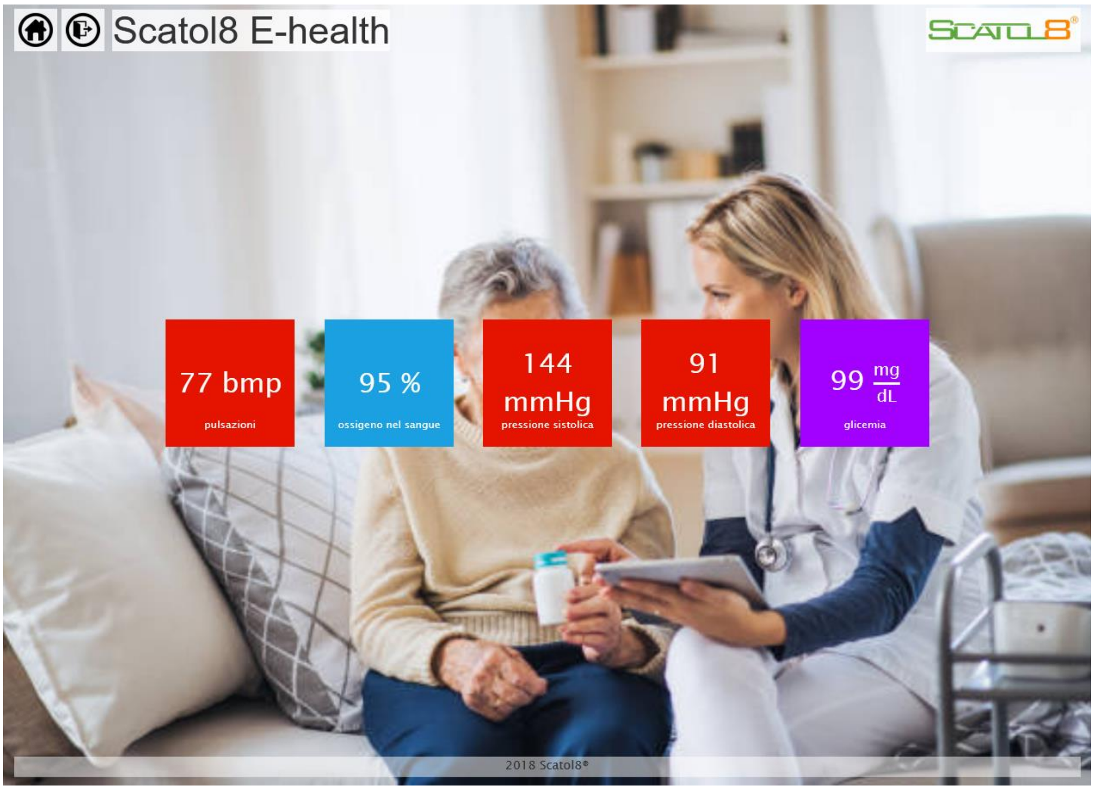

Figure 30: The screen for remote data consultation

The subsequent phases within the Project involve integrating the new Bluetooth sensors to replace the wired ones that have shown limitations in accuracy, as explained earlier. Following that, the system will be installed at the residence of one or more elderly individuals to test the ease of use of the tool.

8.7 Research on remote video communication solutions for the elderly

Within the Project, we also explored how to provide elderly individuals, particularly those living alone in isolated areas, with medical and psychological support through remote communication. The device in question should enable the elderly person to make and receive video calls in a clear and straightforward manner, without the need for complicated intermediate steps that require computer knowledge.

The solution should therefore involve a combination of hardware and software capable of managing video calls and seamlessly sending measurement data to the doctor for the biometric aspect, all while remaining transparent to the end user. The interface is based on a touch screen display that, upon startup, directly shows the available options without requiring passwords or account access in a mode commonly referred to as kiosk mode.
In the following section, we will discuss the different hardware/software solutions, starting with ready-made solutions that are compatible with mainstream operating systems, allowing the device to be used in kiosk mode and interface with dedicated measurement sensors. Subsequently, we will compare the available services for managing video calls.
The work carried out within the Project involved researching these various solutions; however, due to budget constraints and the limited availability of products on the Italian market, it was not possible to purchase and test them.

8.7.1 Ready-to-use solutions

The following table shows some of the ready-to-use solutions that allow the elderly to communicate easily with another person. Some of these solutions do not allow the elderly person to initiate a call but only to respond to incoming video calls.

Product	Website	Brief Description
No isolation komp	https://www.noisolation.com/uk/komp	Costs £700 in the UK, not available in Italy. The elderly can only respond to video calls. It has a single physical button for power on/off.

Ily	https://www.ily.co/app	Similar to a tablet, allows calling and receiving calls from family members using the same app. The project has not been completed since 2016.
Elliq	https://elliq.com/	"ElliQ, the one with the strange shape, priced at over €1000."
Oscarsenior	www.oscarsenior.com/	Designed for care facilities like nursing homes, allows making calls from devices such as generic tablets and PCs. Doesn't seem to be very user-friendly.
Viewclix	https://www.viewclix.com/	Specific tablet for incoming calls and viewing photos. Has an app for relatives. Cost is $300.
Grandpad	https://www.grandpad.net/	Provides a tablet for the elderly for $780/year, while relatives can call from a mobile app. Only available for sale in the United States or for large orders.
Konnekt	https://www.konnekt.com.au/it/	Particularly easy to use, allows calling regular phones and setting up automatic response. Offers purchase, subscription, or rental options.
Amigoclub	https://www.amigoclub.me/it/	A tablet with a simplified interface for use by the elderly. However, it remains a somewhat non-intuitive device. Costs CHF295 for purchase + CHF29/month subscription for two users who want to make calls.
Alexa care hub	https://www.amazon.com/Alexa-Together	Alexa Care Hub can be installed on Amazon Echo Show and allows, in addition to making video calls, monitoring the elderly's interaction with the device and sending prompts to the individual in case of inactivity. The hardware price depends on the version of Echo Show, while the subscription fee is $19.99 per month.

Table 14: Some complete solutions for communication between the elderly and a remote person. (Images are taken from the respective manufacturers' websites

8.8 Operating systems that support kiosk application development

In addition to complete solutions, the research also focused on operating systems that allow the development of kiosk applications. Choosing a non-proprietary solution that can be developed in-house could potentially integrate both the biometric parameter detection system and the calling system within the same kiosk.

8.8.1 Windows

Windows offers excellent possibilities for graphical interface development through Visual Studio software, which allows the development of UWP and Win32 applications using the C# programming language.

Moreover, the Enterprise and Professional versions of Windows 10 allow launching kiosk mode applications directly from the control panel, without the need for third-party tools.

As for hardware, the LattePanda development board is well-suited for this scenario, offering all versions of Windows 10. It also includes an integrated Arduino microcontroller, which addresses the issue of interfacing with external measurement sensors. The cost of the base board with Windows Enterprise is €182.84.

8.8.2 Linux

In Linux, Qt can be used for graphical interface development, which is a cross-platform library developed in C++. However, compared to UWP applications, the graphical elements of Qt are less optimized for touch applications, making their use more challenging in a context like this.

Furthermore, the documentation on kiosk mode is limited to the use of web apps, which are not recommended in projects like this as they do not allow adequate interaction with the hardware, and Python applications, which are also poorly supported for touch screen interfaces.

In terms of hardware, Raspberry Pi is certainly an excellent compromise between purchase cost, performance, and offered functionality. It utilizes the dedicated Raspbian operating system, based on the Linux kernel. The price ranges from €40 to €60 depending on the model.

8.8.3 Android

Android applications have gained significant popularity in recent years. Android Studio can be used as the development software, based on the Kotlin programming language, which has recently replaced Java. However, it still supports Java and also C++. Alternatively, Xamarin can be used, which uses C# and is supported by Visual Studio.

Android can be installed on Raspberry Pi 3B thanks to Emteria, a paid service that, among other features, also allows the development of kiosk applications in the business version. The price for this version is not specified. As for Raspberry Pi 4, Emteria does not currently support it, and the methods found for installation are unofficial. An alternative is the UDOO board, which directly supports Android in different versions. The most economical solution, with Android Marshmallow 6.0.1, is UDOO Neo Basic, costing approximately €45.

Another paid service for creating a kiosk application is Hexnode, which is interesting because it is also supported by any version of Windows, eliminating the need for the Enterprise package. Hexnode offers various packages, with an average cost of around €6 per month.

8.9 Video Calling System

Regular video calling applications require a personal account to access the system. In a context like this, what is needed is an application that can be invoked transparently, using preferably open-source systems that provide libraries for making video calls.

8.9.1 Skype

Skype is the most widely used cross-platform free IP telephony system. It allows for individual and group video calls, as well as instant messaging. Unfortunately, the service is not open source, and the available library, SkypeNet, is obsolete and has not been updated for years. However, Skype can still serve as a starting point for searching for libraries with similar features to SkypeNet in case any are released in the future.

8.9.2 Jitsi Meet

Jitsi is an easy-to-use service accessed through the web that doesn't require registration. It is written in JavaScript and is open source. However, there are no compatible libraries for C# or C++ projects, making UWP solutions and those developed with Qt unusable. Jitsi does provide the ability to embed itself in an application using appropriate APIs. Another alternative could be using a Python script that directly opens the Jitsi web page within the application, as successfully done in other projects (Hackster, 2023).

8.9.3 Tox

Tox is a decentralized, open-source, encrypted platform with video calling, voice calling, screen sharing, and file sharing capabilities. It was not created by a company or organization but by a group of volunteer developers. There are clients available for desktop platforms such as Windows, Linux, and Android. It is written in the C language and is available in multiple programming languages such as C#, C++, Java, and Python, although not all of them are fully supported yet.

8.9.4 RocketChat

RocketChat is a real-time communication platform designed for teams. It is open source and built with Meteor JavaScript. There are C# libraries available for Xamarin applications, while for the use of C++, the documentation is not up to date. Windows usage is not recommended, favoring the use of Linux. There are both free and paid versions that differ in functionality.

8.9.5 Linphone

Linphone is an open-source enterprise and commercial solution for video and voice calls. There are native mobile applications for Android and desktop clients for Windows and Linux. The user interface for Windows and Linux is developed using Qt/QML. Linphone is based on the Liblinphone library, which implements all its functionalities. The library and its dependencies are written in C and C++. Wrapper libraries for Java and C# are also available. It also allows downloading a package in Visual Studio for UWP application development. Finally, there is a well-documented version for Android among those listed.

8.9.6 MixedReality WebRTC

The project consists of a collection of components to help application developers integrate real-time audio and video communication. The components are based on the WebRTC protocol for real-time communication, which is supported by most modern web browsers. The project, by Microsoft, includes libraries written in C++ and C#, designed for use in the Visual Studio environment for creating desktop and UWP apps. MixedReality WebRTC is currently deprecated and no longer supported.

8.9.7 PJSIP

PJSIP is a free and open-source multimedia communication library that implements protocols based on various standards. It combines the SIP signaling protocol with the multimedia framework into a portable, high-level multimedia communication API suitable for almost all systems, ranging from desktops and embedded systems to mobile phones. The documentation may not be up to date, although the latest version of PJSIP is recent, indicating that the project is not abandoned.

The following table summarizes the main features of the open-source software libraries identified for implementing a communication system over the internet network:

Library	Programming language it is developed with	Available platforms	Languages in which the libraries are available
Jitsi Meet	Javascript	Windows, Linux, Android	Javascript libraries APIs to integrate Jitsi into applications
Tox	C	Windows, Linux, Android	Python3 for Toxigen client C++ for qTox client C for uTox client
RocketChat	Meteor Javascript	Windows, Linux, Android	C# for Xamarin Kotlin for Android
Linphone	C, C++	Windows, Linux, Android	C++ library C# wrapper Linphone for Android
MixedReality-WebRTC	C#	Windows	C# and C++ libraries
PJSIP	C	Windows, Linux, Android	Wrapper for Microsoft.NET C++ wrapper Library for Android

Table 15: Key features of open-source libraries for developing a video calling system

9. Tools for evaluating system elements and methodologies to facilitate public decision-making

The feasibility of a project or the comparison of different projects can be evaluated through quantitative techniques, based on objective values, or through more qualitative techniques which, despite the need for interpretation, are faster and easier to apply in the case under analysis.

This work proposes an integrated system in which different elements are interconnected to facilitate decision-making processes for public entities, particularly in evaluations related to territory safeguard projects and the implementation of remote medical monitoring systems. The integrated system comprises various elements (such as natural areas and resources, inhabitants, as well as medical sensors and instrumentation) that are difficult to compare with each other.

When using quantitative techniques, it is necessary to find a common factor as the basis for the analysis in order to quantitatively link a specific action to its effects (expressed in terms of costs and benefits) on all members of the community. Following the logic of "what gets measured gets managed" (Sukhdev, 2011), it should be possible to reason with numbers and thus economic values even for goods that are not usually evaluated in such a way. This involves evaluating goods and services that do not have a market, as for those that do, their price can be used, although it is not without criticism as it is often an imperfect tool.

In the specific case, many elements of the integrated management system have a price: for example, the sensors for territory monitoring, the sensors for remote medical monitoring of patients, and the associated cost of remote control based on parameter variations, as well as the cost of transportation (which can also be seen as a benefit of non-movement in the case of telemedicine implementation, etc.). However, other elements such as ecosystem services in territorial analysis and the value of waiting time (which represents a well-being parameter rather than movement, hence a monetizable parameter) to reach equipped medical centers do not have a price.

9.1 Ecosystem services

According to the definition provided by the Millennium Ecosystem Assessment (Millennium Ecosystem Assessment, 2005), ecosystem services are "the multiple benefits provided by ecosystems to humankind," which refers to the set of goods and services that natural systems offer to human beings. This study presents a systematic analysis of ecosystem services and their capacity to respond to human impact, highlighting how ecosystems have been increasingly and rapidly modified by human activity over the past sixty years, resulting in irreversible natural loss. This is accompanied by a significant increase in ecosystem costs, which progressively leads to a loss of well-being over time.

Ecosystem services can be divided into four categories:

- **upporting services**: such as soil formation, nutrient cycling, etc. These services enable life on Earth by providing other ecosystem services.
- **Provisioning services**: including the supply of food, water, raw materials, etc. These services involve the production of goods and services that support the livelihoods of living organisms and can be governed and managed due to their inherent nature.
- **Regulating services**: such as climate regulation, air quality regulation, waste decomposition, etc. These services perform control functions over natural processes.
- **Cultural services**: encompass all intangible and landscape-related goods that hold educational, religious, and cultural significance for human beings.

Among the various benefits that the FragMont Project aims to consider in the cost-benefit analysis, a significant position is occupied by those connected to ecosystem services. However, before explaining how these elements are considered in the economic evaluation, it is necessary to address the spatial extent of the produced benefits.

When considering ecosystem services provided by a specific territory, an important factor to consider is the spatial scale of the produced benefits (Gibson et al., 2000). The classification offered by the Millennium Ecosystem Assessment encompasses a wide range of ecosystem services with significantly different impacts on humankind. On one hand, supporting and regulating services are generated by large-scale chemical, physical, and biological dynamics, whose effects extend not only to the area of interest but also to the entire natural environment. For example, the carbon sequestration process performed by a forest in Val Sesia can have local effects but is part of a much broader and complex global process, producing benefits for the entire planet. On the other hand, provisioning and cultural services generate more localized and specific benefits that are tangible and easily quantifiable, particularly at the local level. Using the example of the forest in Val Sesia, the precise production of timber derived from it can directly benefit the community that depends on the extraction of this resource for their sustenance (Banerjee et al., 2013).

In summary, although the provision of ecosystem services occurs at a local level, the magnitude of the associated benefits strongly depends on the type of ecosystem service in question (den Uyl and Driessen, 2015). It becomes useful, therefore, to map and recognize the types and boundaries of ecosystems based on ecological and socio-economic criteria. However, if this aspect is not properly managed, there is a risk of conducting erroneous evaluations during the analysis.

9.2 Economic evaluation of ecosystem services

The importance of economically evaluating ecosystem services is closely related to the fact that they can be integrated and compared with the same values as other goods, thus allowing their integration into decision-making processes.

When the different components, despite the necessary distinctions and assumptions, have an economic value (in cost evaluation, but especially in benefit evaluation, various techniques have margins of uncertainty), it is necessary to identify and use a methodology that allows for choices among different projects, including the hypothesis of a null project (not implementing any strategies at the territorial or health level).

The estimation of the value of ecosystem services can be done using three different approaches to analysis: qualitative, quantitative, and monetary (ten Brink, 2011). The monetary approach is the most commonly used and ensures effective dialogue with public institutions (Christie et al., 2012).

The objectives set by the FragMont Project require a relationship between the costs associated with prevention and those resulting from the potential loss of ecosystem services following a natural event, taking into account the challenges related to the possible isolation of vulnerable individuals. Given this premise, the choice of the method for the economic valuation of ecosystem services will have implications for the final cost-benefit analysis, which will involve healthcare costs, costs related to monitoring and territorial prevention, and costs associated with the loss of ecosystem services.

Figure 31: Example of rescue in isolated area. Image automatically generated by Bing AI

During the development of the project, there was a question about the most appropriate approach to integrating the value associated with ecosystem services into the cost-benefit analysis, and particularly which types of ecosystem services to focus on. In fact, the management system proposed by FragMont is aimed at municipal administrations interested in identifying optimal solutions for their own territory. In such a context, it is useful to prioritize a pragmatic approach that takes into account the most tangible and quantifiable ecosystem services for the specific territory, namely provisioning services.

In some cases, an economic valuation of ecosystem services that does not align with the specific needs of the administration could lead to misleading choices regarding the protection of the relevant territory, potentially generating negative repercussions on other ecosystem services as well.

Considering that the benefits humans can derive from ecosystem services can be categorized as “use values" and "non-use values," and that use values can be further distinguished as "direct," "indirect," and "option" values, the valuation approaches for provisioning services can be identified within these classifications (Isabel Mendes, 2012). In the context of the project, administrations should implement an approach that ensures maximum benefit, not only in ecological terms but also economically and socially.

Given these premises, it can be argued that in the economic evaluation of provisioning services, the most relevant values to consider are direct use values and option values, which are associated with the potential future use of natural resources within the municipal territory. Going back to the example of the Val Sesia forest, the useful value to be included in the cost-benefit analysis for the FragMont Project is directly related to the direct consumption of the relevant resources: the economic value associated with timber, water sources, food availability, etc., that can be consumed immediately or preserved for future use. Therefore, estimating these benefits can be done by considering market prices for these resources and discounting them over time. However, during the various discussions aimed at understanding which tool may support better administrations in quantifying these values, the hypothesis of complementing the monetary quantification of the ecosystem value of various natural resources with a visual and qualitative representation of their magnitude was considered.

As will become clearer in the section dedicated to the argumentation of the decision tree, specifically in paragraph 10.1, the idea behind this approach is to define, through interaction with the public decision-maker, a mapping of the municipal area for territorially fragile areas, accompanied by the identification of natural resources falling within the definition of provisioning services. This will allow for the overlaying of two geographic layers, indicating where, based on territorial vulnerability, the presence of natural resources particularly important for community sustenance may be threatened by the occurrence of an extreme event.

The presence of more or less at-risk ecosystem services will be highlighted by a color scale ranging from green to red, providing an immediate and intuitive understanding of the extent of damage that the occurrence of a natural event can have from a social, economic, and ecological perspective. This will enable the evaluation of the presence of ecosystem services from a geographic-territorial point of view and understanding the ecosystemic importance they hold in specific areas.

9.3 Cost-benefit analysis

Regarding the comparison of monetized values, cost-benefit analysis is often used. It is a methodology that emerged in the 1930s when the US government recognized the need to establish specific guidelines to guide the choices of public works to be implemented.

In Italy, cost-benefit analysis began to be used in the 1980’s with the establishment of the Fund for Investments and Employment (FIO) in 1988, through Law 181/82. According to this law, in order to access FIO funding, central and regional public administrations had to submit an CBA (Costs and Benefits Analysis) along with their investment proposal to the Evaluation Unit for Public Investments (under the Secretary of Economic Planning).

The Evaluation Unit then expressed its judgment on the economic and technical value of the proposals, as well as their costs and benefits, based on the results presented in the CBA.

The objective of cost-benefit analysis is to identify the best among multiple projects (or, in the case of a single alternative, to verify that the costs are lower than the benefits). As can be inferred from its historical background, this methodology originated in the public sector to maximize the utility of a community and primarily address "market failures," such as externalities, public goods, absence of markets, and imperfect prices, which required a different approach from the traditional methods used in the private sector.

The assessment of the feasibility of the project can be carried out by two major economic entities: the private operator and the public sector. The former compares the costs and revenues derived from the project's execution, emphasizing the financial aspect, while the latter focuses on the economic aspect, aiming to maximize social welfare.
A project is considered more advantageous when the net benefit, obtained from the difference between benefits and costs, is greater.

There are at least two aspects that make this reasoning of ordering different alternatives by economic convenience complex. The first aspect relates to the need to determine and evaluate costs and benefits of different entities, often in the absence of a market or with distorted prices. For instance, to assess the CBA of a monitoring system, costs to consider include the initial purchase or development cost, installation, maintenance, upgrades, and potentially replacement costs. Furthermore, the cost of training personnel to operate and interpret the system's output should also be factored in. Comparing these costs against the potential losses prevented by early detection and effective response, guided by ISO management systems, can help gauge the system's value.

The second aspect involves identifying a time horizon and discounting various future flows to present value. Within the context of monitoring system and risk mitigation strategy, it is crucial to assess long-term benefits and cost-effectiveness, since benefits tend to be found more in the long run than in the short or medium run. This complex task may be carried out shifting the perspective from viewing these measures as pure costs to seeing them as investments in safety, resilience, and sustainability. Long-term benefits could include saved lives, prevented property damage, and the preservation of ecosystems. These benefits, however, must be measured against the effectiveness and cost of the monitoring and intervention strategies implemented.

From an operational perspective, it is necessary to proceed with the identification of the criterion to determine whether and to what extent the project is advantageous. To achieve this result, we will need to use methodologies that are the same as those used in evaluating any similar private investment, such as net present value, internal rate of return, or payback period. The first two are certainly the most commonly used.

However, when it comes to the values of interest, the process of assigning monetary values is not entirely possible, or rather, it is not possible without a great deal of uncertainty due to the numerous estimation steps required for goods that do not have a market. This necessitates relying on numerous assumptions to construct the theoretical framework.
This aspect leads us to approach the analysis from a semi-quantitative perspective.

10. Guidelines applicable to territorial and healthcare management

The FragMont Project aims to define the requirements for an integrated, technical, and economic management system supported by data. It seeks to identify the necessary elements to govern situations of fragility in mountainous areas and improve their prevention and management. These fragilities are influenced on one hand, by the exposure of territories to hydrogeological risks and, on the other hand, by the conditions of the population. The project intends to provide municipal administrations with arguments to formulate their requests and make informed decisions. It enables them to develop comprehensive plans and programs with actions to implement in their respective territories based on a priority order.

One requirement of the system is its applicability to diverse realities, even those that may be significantly different from one another. Therefore, the architecture of the decision tree underlying the system has been developed to allow municipal administrations to consider various situations that can be genuinely identified by the local territory and population.

The management system must be structured in a way that, once one or more critical situations are identified, it indicates the best practices to be implemented to resolve or mitigate the identified issues or to consciously avoid them. The added value that makes this management system innovative and effective lies in its support for cost-benefit analysis related to each alternative examined using the decision tree. Consequently, it guides public decision-makers in identifying the optimal solution not only from a territorial and social perspective but also an economic one. As already noted, ISO management system may be the proper tool to assure reliability of the monitoring system, since it provides an organized framework to manage operations and align the goals towards sustainability.

With this regard, four main characteristics of ISO can be identified as crucial to ensure the sustainability path:

1. **Setting measurable objectives:** Establishing clear, measurable objectives is crucial to the success of any initiative. By integrating open-source technologies and telemedicine within the ISO management systems, these goals could be defined in terms of improving healthcare access, enhancing service quality, or reducing costs. Additionally, sustainability objectives could be set around decreasing environmental impact, creating local employment, or upskilling community members.
2. **Establishing operational controls:** These controls are set procedures designed to ensure the consistent and efficient operation of processes. In the case of implementing telemedicine solutions, controls might include quality assurance protocols for data transmission, steps for equipment maintenance, or guidelines for user training.

3. **Ensuring stakeholder engagement:** Stakeholder engagement is vital in understanding the needs, expectations, and potential roadblocks to successful implementation. By engaging with local communities, healthcare providers, policymakers, and other stakeholders, the deployment of these solutions can be tailored to the specific needs of the region. This can also foster a sense of ownership and responsibility among stakeholders, improving the long-term sustainability of the solutions.
4. **Conducting regular reviews for continuous improvement:** Regular monitoring and evaluation are essential to ensure that the implemented solutions are effectively meeting the intended objectives. Feedback from these reviews can be used to continually refine and improve the processes, further increasing their efficiency and impact.

Particular importance in this context is given to new open-source technologies, especially IoT devices, for monitoring hydrogeological disasters and evaluating how to reduce the isolation of people in hard-to-reach environments. For example, remote monitoring of medical parameters or the habits and activities of the elderly or vulnerable individuals, with a view to reducing costs associated with the travel of healthcare personnel.

The sustainable implementation of open-source technologies and telemedicine solution in mountainous regions is a complex process, laden with various challenges. These might include physical obstacles like difficult terrains and limited infrastructure, as well as sociocultural factors like local knowledge gaps, community participation, and acceptance. These challenges emphasize the importance of meticulous planning, judicious resource allocation, and capacity building.

The paper's practical examples would ideally demonstrate how these strategies have been applied in real-world scenarios, highlighting their impact on managing fragility in mountain regions. These examples could range from community-based telehealth initiatives to regional deployment of open-source healthcare solutions.

10.1 Design purposes of the decision tree

To achieve the implementation of the integrated management system, it was necessary to define a decision tree that encompasses the wide variety of situations that an administration may face in order to protect its citizens. This structure systematizes every possible choice that the Mayor may encounter in their decision-making process. In the implementation phase of the Project, in which this report was prepared, the decision tree is presented in the form of a conceptual map.

The future developments of this system involve creating an interactive tool to be made available to administrations intending to implement this type of analysis in their municipal territory. In order to obtain real feedback from the product to support the decision-making process, the development of a computer system will be necessary to link the information available to the municipal administration with official statistical data.

This information, contained in the Database, will play a central role in ensuring the practical operation of the decision tree.

10.2 Development of the decision tree

The work focused on the development of a decision tree that integrates all the variables to be considered, as envisaged by the FragMont Project, both in terms of the territorial and medical aspects.

The decision tree underwent multiple revisions, characterized by increasingly detailed and specific reflections, allowing for a complex yet linear articulation of all the hypotheses and situations that the public decision-maker may encounter in defining a prioritized scale of interventions to be carried out in their municipal territory. In total, four different versions of the decision tree were developed, maintaining a historical record of them, which are accessible to clarify any doubts regarding the final version's drafting.
Throughout this report, the design choices that have been made will be discussed to contextualize the reflections that led to the final structure of the decision tree and provide food for thought for potential future adaptations. These adaptations may involve identifying conditions for interoperability with other existing or ongoing projects' tools to improve the system's efficiency.

10.3 Structure of the decision tree

Since its initial development, the structure of the decision tree has been designed to separate the two areas of interest (territorial and medical) so that the study of geographic characteristics on one hand, and socioeconomic aspects on the other, does not overlap. This allows the public decision-maker to proceed with evaluations related to the two domains concurrently but autonomously. This consideration is also useful for identifying funding sources relevant to the implementation of programs, which come from distinct areas.

As will be further illustrated and argued later on, in certain sections of the decision tree related to territorial evaluation, aspects related to telemedicine will be considered, particularly concerning the analysis of accessibility in specific locations within the municipal territory. However, the study of the two areas of interest will remain separate and easy to interpret.

The medical section of the decision tree is not solely focused on analyzing the health status of the fragile population (elderly and/or individuals with chronic illnesses), but it aims to delve into the study of various socioeconomic aspects related to the municipal territory, providing a comprehensive view of the context in which the public decision-maker can define intervention choices.

Among the information to be investigated are:

- Distribution of population by age group
- Distribution of population by pathologies
- Number of active clinics in the municipality
- Physician-to-population ratio
- Municipality's population density/area ratio
- Tourist-to-population ratio

Having a complete understanding of the context in which the administration must make its decisions can significantly influence the decision-making process, taking into account the specificities of the territory. This would allow for a thorough consideration of each specific situation unique to the examined municipality, thus avoiding the replication of identical interventions in disconnected territories.

The section dedicated to the analysis of geographic characteristics of the territory aims to evaluate all the interventions that have been carried out and potentially feasible interventions that may affect the most at-risk areas of the municipal area. In the initial versions of the decision tree, the study was presented in the same manner for landslides, avalanches, and floods. After a preliminary review of the structure of the decision tree, sections related to landslides and avalanches were combined into a single category referred to as "gravitational events." This simplifies and streamlines the construction and interpretation of the decision tree.

Throughout the various revision phases of the decision tree, there were multiple considerations to divide the structure into two parts to improve readability and understanding. However, the final choice was to maintain the original structure, which encompasses the two fields of investigation, territorial and medical.

10.4 Introductory section of the decision tree

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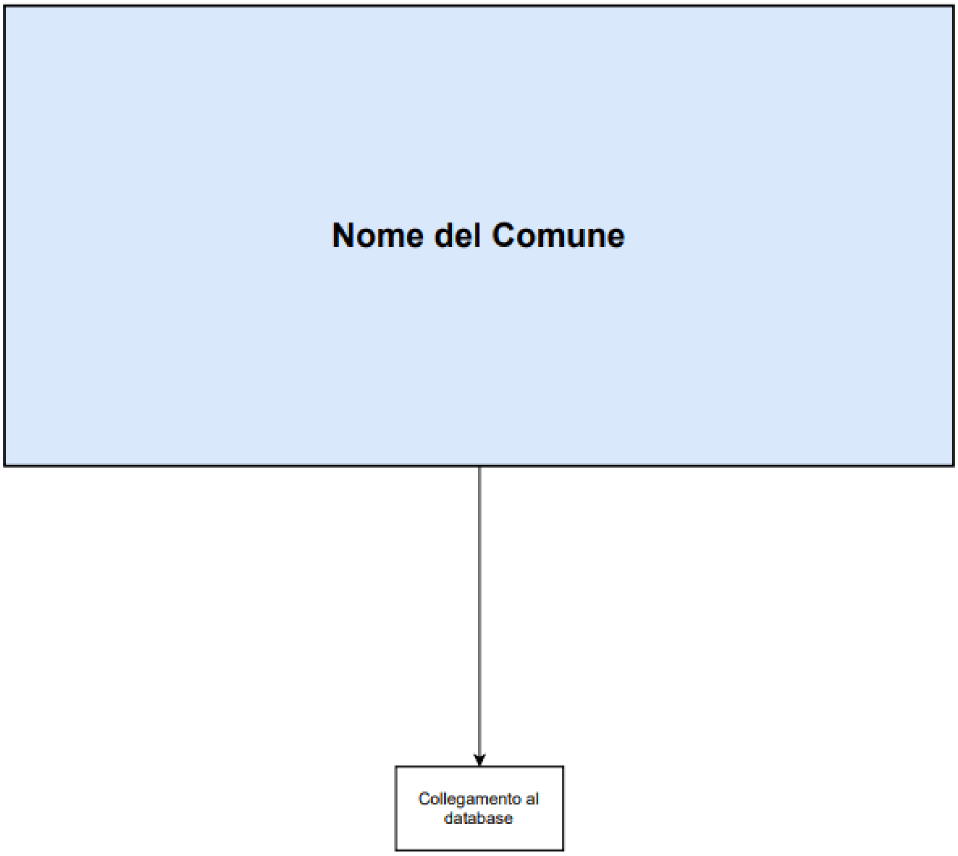

Figure 32: Initial section of the decision tree

The interaction between the decision tree and the database becomes clear and understandable from the first step when reading the decision tree. By entering the name of the municipality in the first box, the final version of the system is designed to initiate an interactive process that extracts all relevant information from the database and incorporates it into the decision tree, based on the available data specific to the examined municipality.

The next step predominantly focuses on territorial aspect and requires the public decision-maker to gather all the necessary documentation to initiate a proper study of the territory. Although this step mainly concentrates on the study of one of the two areas of interest, it may be considered in the future to include documentation related to social aspects as well, which are essential for framing the initial situation in which the municipality operates. This would provide all the indicators necessary to characterize the municipality for the variables of interest. The same data could be represented in dedicated dashboards with color solutions to highlight critical aspects or areas deserving attention or positive aspects.

To facilitate this phase, a list of all the documents that the administration can consult to comprehend the entirety of the required documentation has been included on the margin of the decision tree. Specifically, these documents are those that the municipality is legally obliged to prepare in order to understand its territory. However, it does not necessarily mean that these reports are sufficient to comprehend the ongoing dynamics. This step, similar to the compliance verification in the initial environmental analysis according to ISO 14001, constitutes an added value in itself. The administration can precisely identify any non-compliance and take action to remedy it.

For the knowledge of the territory to be comprehensive and aligned with the objectives of the FragMont Project, the mentioned documents must be up-to-date and effectively observed by the administrations that have prepared them. Another fundamental element to be aware of is the measures taken following past events, in order to construct a broad and well-structured overview. It is necessary to understand whether the documents correspond to actual implementations and any updates (monitoring systems, evacuation plans, civil protection plans). Among these documents, some are required by law, but they may have also been developed before an event occurred, based solely on territory monitoring. Therefore, once this documentation is obtained, it will serve as the basis for analyzing the municipality's territory, considering its level of detail and adequacy.

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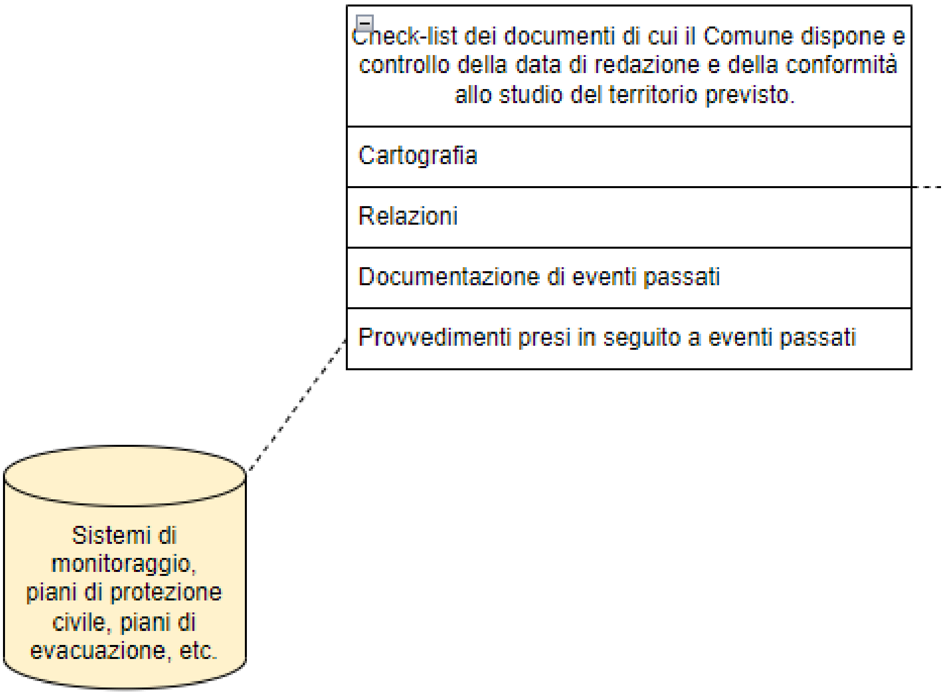

Figure 33: Retrieval of documentation required for a proper study of the territory

In case some of these documents are missing or do not meet the requirements of the FragMont Project, the municipality is encouraged to recheck the available material, update it, and only then proceed with an evaluation that is as suitable as possible to the project's objectives using this tool.

10.5 Study of the geographical characteristics of the territory

As highlighted earlier, there are two types of events considered in the territorial section of the decision tree: gravitational events and flood events. The decision to consider these event types was made during the project's development. However, it does not exclude the possibility of including fire-related scenarios among the expansion scenarios considered. This is due to the increasingly frequent episodes, particularly during the summer period, which pose a concerning threat to the natural and social balance not only in Italian mountain areas characterized by extensive vegetation cover but throughout the national territory.

For each type of event, a series of questions is posed to guide the decision-maker in understanding the current state of implemented works and the potential intervention space to address the at-risk territory. The quantity and structure of the questions have not remained unchanged in every version of the decision tree. In fact, the final structure appears significantly more articulated and complex than the previous versions, thanks to the progressively deeper knowledge acquired through the research group's discussions, aiming to examine every aspect deemed useful for a comprehensive understanding of the territory.

- Have post-mitigation measures been implemented?
- Have preventive measures been addressed?

These initial questions were introduced in the fourth and third versions of the decision tree, respectively. Their objective is to define the status quo in which the public decision-maker operates. The choice to include these aspects in the decision tree has evolved over time in response to the need to weigh the administration's choices within the most comprehensive framework possible.

Following these questions, more targeted queries of a purely geographic (GPS coordinates) and economic nature regarding the costs incurred for the implementation of such interventions are presented. This way, archives related to sites previously subject to evaluations and safety measures will be obtained for both types of interventions. These archives will contain information regarding the costs and benefits associated with each considered intervention, allowing for the weighting and comparison of various activities and defining a scale of priority regarding what has already been implemented. Ultimately, the effectiveness of the implemented interventions will be assessed.

A similar data collection will be conducted for the medical part, where archives related to medical and health fragility situations in the municipal territory will be developed. As elaborated upon later in a more detailed manner, the purpose of these archives is to assist the administration in the integrated analysis phase between territorial and medical data concerning the observed municipal territory.

The second question, in the fourth version, is accompanied by the following question, already present but adapted in previous versions:

- Can additional preventive actions be implemented?

Its reworking during the decision tree update clearly demonstrates how the structure has been refined and improved over time to consider any specific situation that the administration may encounter.

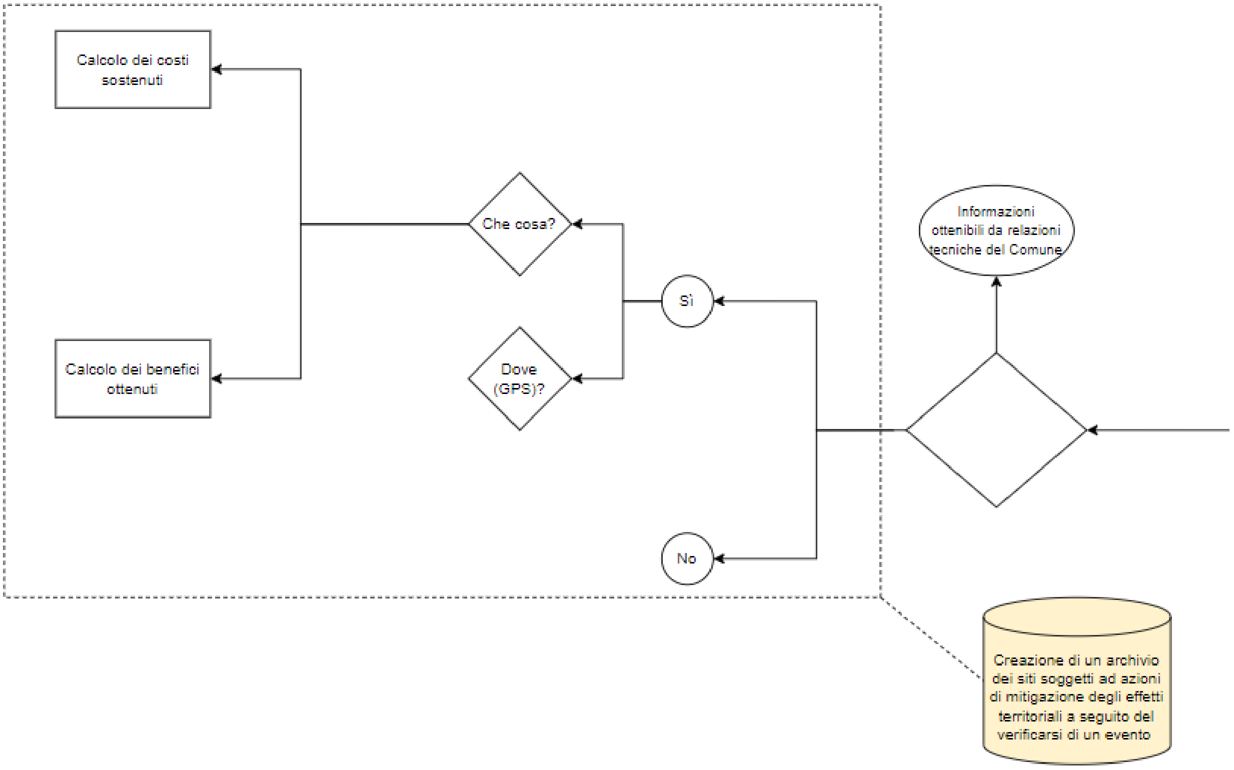

Figure 34: Creation of geographic coordinate archives

Continuing with the other questions that the public decision-maker must answer within the structure of the decision tree, we encounter questions of this kind:

- Can pre-event monitoring actions be implemented?
- Can additional mitigation measures be implemented?

While the first question has been present in the decision tree since its initial versions, the second question was introduced in the fourth version. Generally, it can be considered that the concept of mitigating extreme events emerged during the development of this study, complementing the predominant concept of adaptation within the FragMont Project. The research group aims to develop a comprehensive framework of solutions, both active and passive, prior to and following the occurrence of natural events, for the administration's choices to be truly based on an understanding of any possible scenario that may arise.

Unlike the questions analyzed earlier, these inquiries serve to understand the practical feasibility of monitoring and mitigation measures in the municipal territory. In both cases, the ultimate goal, as partially achieved in the previous section, is their economic evaluation in the form of an estimate, ranging between a minimum and maximum value.

To simplify and enhance the readability of the territorial section of the decision tree, during the various revisions, the hypothesis of dividing the graph structure into two parts has been considered: one dedicated to collecting all the information to obtain a comprehensive understanding of past works, and another dedicated to assessing all possible intervention hypotheses. However, despite its complexity, the decision tree has been maintained in its original form because its interpretation has proven to be linear and comprehensible.

Still within the territorial section of the decision tree, particular attention has been given to understanding the impact of the natural event under consideration on two central aspects within the FragMont Project: ecosystem service provision and accessibility to inhabited areas.

10.6 Ecosystem service provision

The choice to focus attention within the decision tree solely on provisioning services has been translated conceptually into the creation of a hypertext link, as discussed in relation to the case of the documentation that the municipality should obtain for a proper analysis of the territory (Figure 35).

This list enables the administration to indicate the types of resources compromised by the occurrence of the natural event, even in the absence of specific knowledge and skills aimed at identifying and translating the value of natural elements into ecosystem services.

This allows the system to simplify the extraction of information useful for the economic evaluation of the loss of ecosystem services, with the valuable support of the non-expert public decision-maker. It will be the system itself, at a later stage, to rework and process this information, also providing a visual representation as a basis for the associated economic analysis. This will allow for the assessment of market prices related to the resources in question and the extraction of a visual map of the presence of these resources, which, as mentioned throughout this discussion, will overlap with a mapping of the municipality divided into territorially fragile areas.

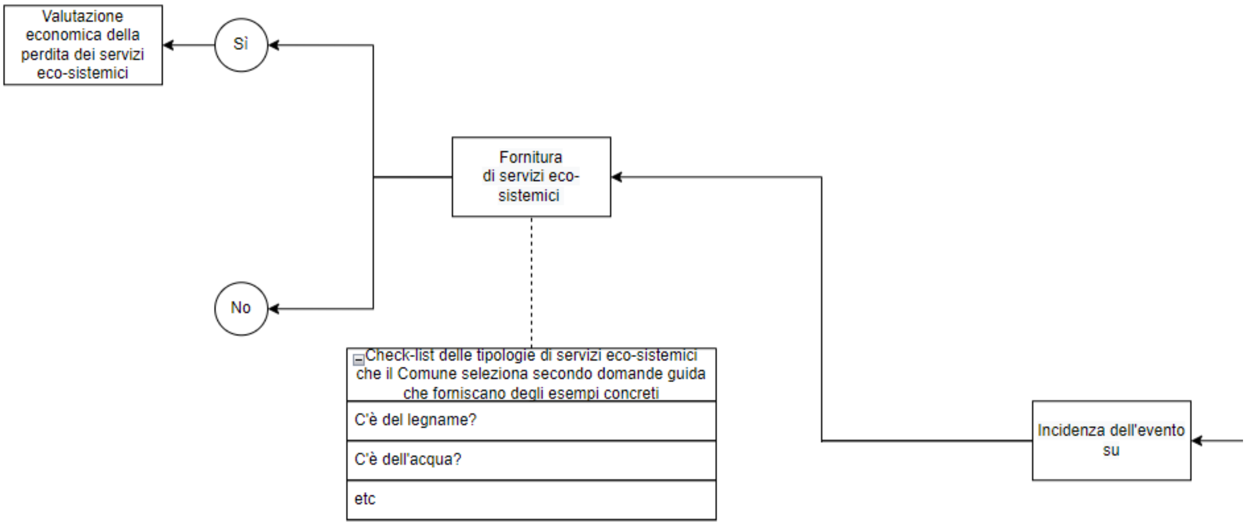

Figure 35: Analysis of the provisioning services involved in the occurrence of the natural event

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10.7 Definition of territorial emergency and health emergency

In various discussions regarding the revision of the decision tree, a concept that has been extensively debated is that of "emergency." Often, it has been unclear what exactly is meant by this term.

When referring to a territorial emergency, it encompasses the situation of a natural event occurring, which generates a series of negative effects with repercussions on the environment and the lives of the entire population. On the other hand, when referring to an emergency for a vulnerable individual, it pertains to a condition specific to the individual, such as the exacerbation of a pre-existing condition, the incidence of risk factors for the elderly, or significant variations in monitored parameters.

The telemedicine system is an independent tool located at the homes of fragile patients, designed to monitor the ordinary evolution of a medical condition. This device is not influenced by the concept of emergency because its functionality remains unchanged in any circumstance, whether operating under ordinary or emergency situations, and it is not affected by exogenous conditions such as the occurrence of adverse weather events.

In conditions of a territorial emergency, as hypothesized in the case of FragMont, which assumes the interruption of access routes to sites where fragile individuals reside, the value of the telemedicine system strengthens. It becomes necessary to acquire the patient's parameters remotely. The monitoring of parameters for the vulnerable individual, which would typically occur under ordinary territorial conditions, would continue without any repercussions on the isolated individual during an emergency situation. In the absence of this system, there is a high probability that the patient would experience severe repercussions following the occurrence of the event due to the inability to transfer from one location to another, both for the affected individual and the medical personnel.

Considering the objective of the FragMont Project, the research group has concluded that the use of the telemedicine system can be justified under normal circumstances due to exogenous variables such as the lack of doctors in the area and the distance of the sites from urban centers. In the event of an emergency, the value of this system strengthens as it ensures stable and secure communication regardless of the patient's medical conditions. Therefore, telemedicine is a tool that should be implemented independently of the occurrence of a territorial emergency.

10.8 Accessibility to inhabited areas and telemedicine

Based on the arguments presented in the previous section, this paragraph plays a central role in the FragMont Project, as the isolation of individuals and accessibility to the most remote areas in the mountain municipalities are fundamental elements of this study.

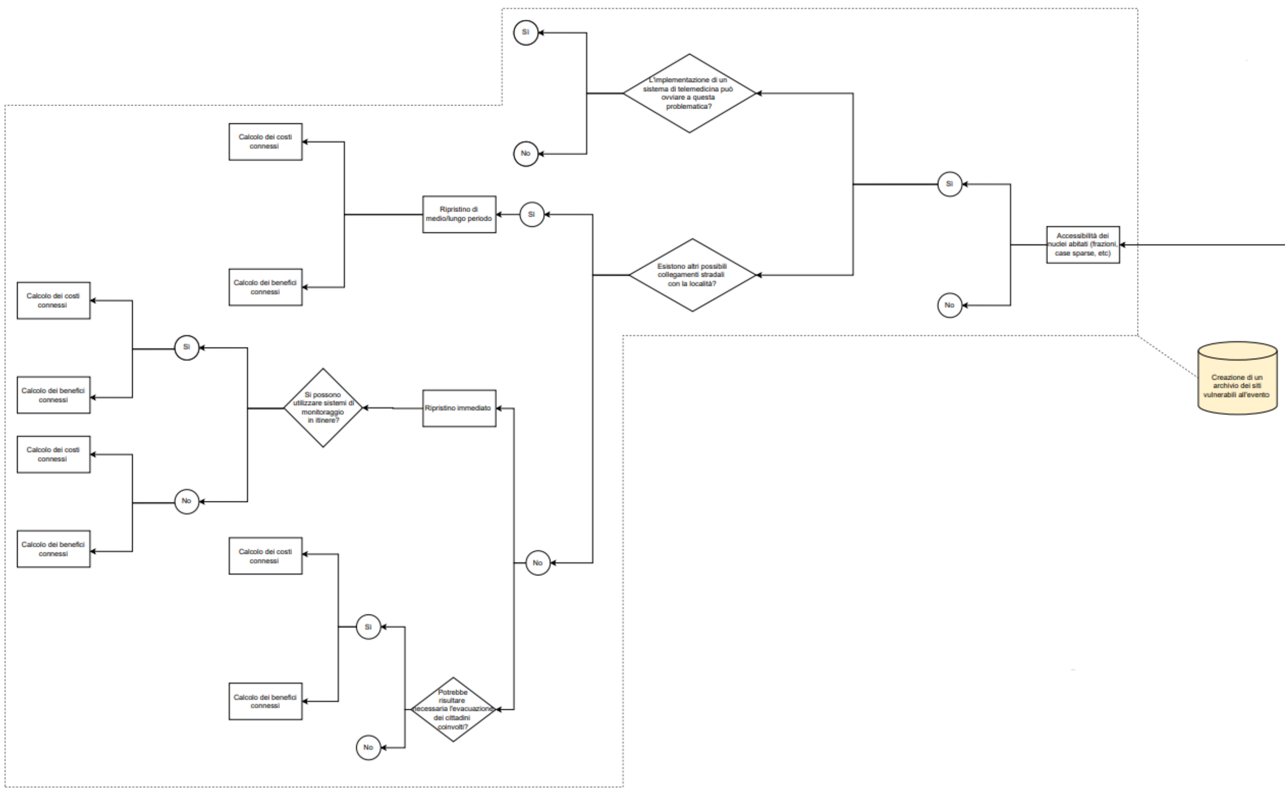

Figure 36: Creation of archives of the most vulnerable sites from a hydrogeological perspective

In this case as well, based on the initially collected and further investigated documentation, as well as the local administrations' knowledge of the territory, the decision was made to create an archive of sites that are potentially susceptible to the occurrence of the examined natural event (such as gravitational or flood events).

Unlike the previous case, it would be preferable to map vulnerable areas rather than pinpointing specific sites. The locations being referred to should not be connected to events that have already occurred and/or past interventions. In the planning of the interactive tool to be provided to the public decision-maker, this archive will be of particular importance since it needs to interact with a similar medical archive, where the locations of vulnerable individuals residing in the municipal territory will be recorded.

Regarding the information reported in the previous paragraph, special importance is given within this archive to sites accessible only by a single road. Depending on how the administration responds to the question, "Are there any other possible road connections to the locality?", the scenario that emerges changes drastically. An affirmative response involves restoring the medium/long-term situation, with a consequent expenditure of energy and resources that can be modulated based on the situation and the municipality's economic availability. On the other hand, if the response is negative, meaning there is no possibility of reaching the area through alternative roads, the described situation of territorial emergency arises.

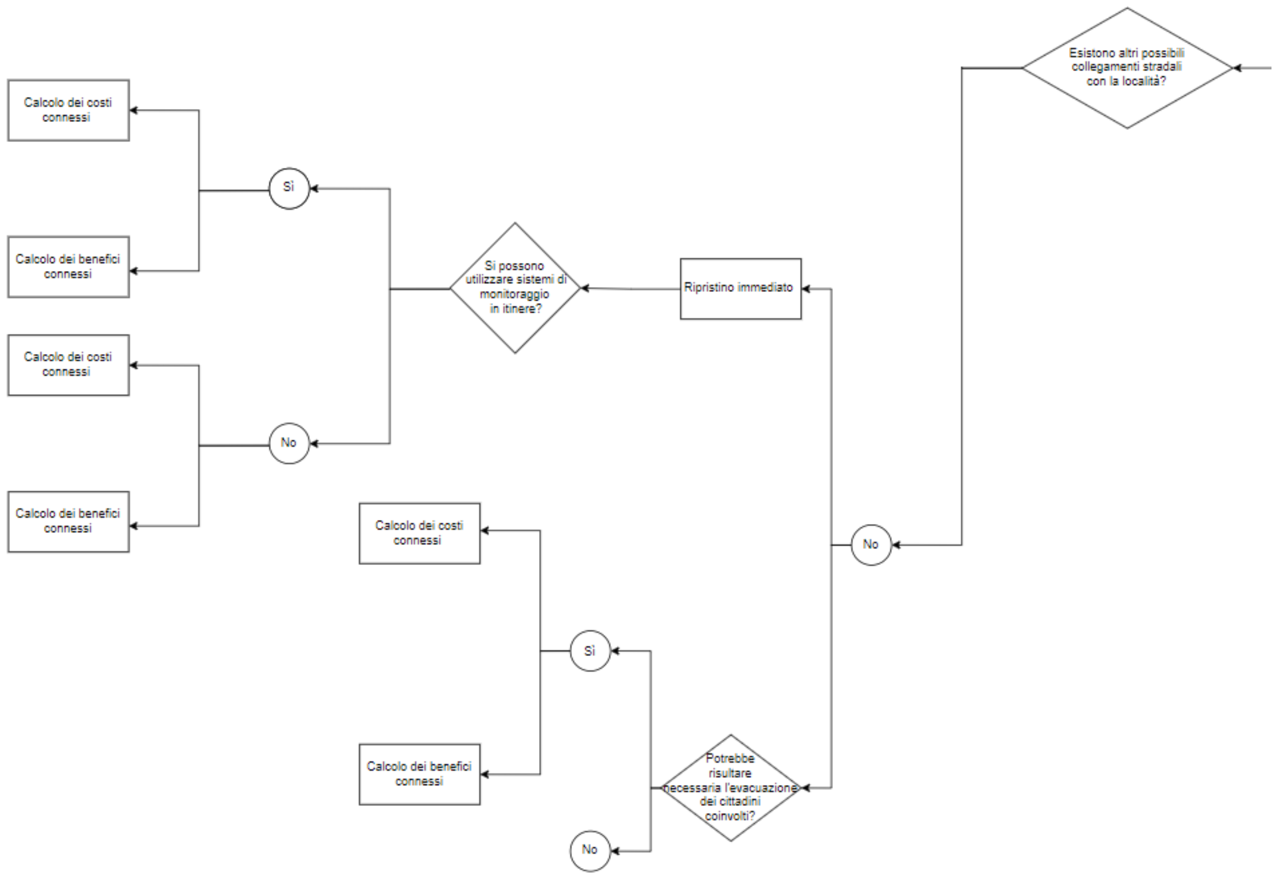

Figure 37: Section of Figure 26

The analysis following the need for immediate restoration focuses on the economic evaluation of the necessary interventions, which can be supported by the use of monitoring systems during the process. Simultaneously, an additional question is raised to assess the severity of the situation generated by the calamitous event, namely whether the possibility of evacuating the affected citizens should be considered. In this case, the telemedicine system may not be compatible with ensuring the safety of the territory. This is a worst-case scenario that is useful to know in order to understand the territorial situation in which the administration may need to operate.

10.9 Monitoring Technology for the Territorial Area

In order to test the available sensors for observing natural disasters, the possibility of simulating a landslide in Moncucco Torinese and monitoring its progress has been considered, albeit in an expedited form. The landslide would be detected through the analysis of images (Digital Image Correlation, Change Detection...) acquired via webcams or commercial cameras, made possible by a technology already developed for two different projects by CNR-IRPI, which has already proven its functionality (Dematteis et al., 2021; Guenzi et al., 2022). The system in question consists of a webcam integrated with an extensometer, allowing continuous monitoring of slope deformation, and in the event of an occurrence, an immediate notification would be sent to the relevant authorities. In the case of Moncucco, where the slopes are composed of soil, the extensometer will not be installed, and monitoring will solely rely on webcams and image analysis.

In this specific case, monitoring the gravitational phenomenon does not require excessive image detail, so the approach chosen is to detect a variation in colors, which is preferable to evaluating changes in geometries for identifying the initiation of the phenomenon. If the recorded color variation can also be associated with rainfall data, it would further enhance the ability to identify the event and/or monitor its development. The instrumental cross-check would allow the analysis software to minimize false positives.
The type of instability being monitored is rapid and of small dimensions but still capable of blocking a road. Its occurrence is quite frequent, making it challenging to have extensive control over the entire territory. This consideration leads to the awareness that complete territorial control is not feasible but requires a selection of specific areas for analysis.

Before proceeding with the monitoring of this type of event, it would be necessary to conduct a susceptibility analysis of the hydrographic basin, supported by statistical analysis (Cignetti et al., 2021, 2019). Additionally, for optimal study completion, human presence would be required to monitor areas not covered by sensor monitoring but can be easily managed.

Alternatively, another monitoring hypothesis would be to acquire data from the study area via satellites, which are available for free on the website https://egms.land.copernicus.eu/, maintained by the European Environment Agency. However, this technology would not be suitable for the type of landslide being evaluated in the territory of Moncucco Torinese for the reasons discussed above. Satellite observation is preferable, for example, for extensive and slow landslides as well as avalanches because it allows for understanding the event's progression over time through the analysis of historical series (Cignetti et al., 2020). For this reason, satellite data analysis is more suitable for the case of Alagna Valsesia and not for Moncucco Torinese.

10.10 Study of the Socio-Economic Characteristics of the Territory

Similar to the detailed analysis of the territorial section of the decision tree that was previously conducted, we will now proceed with an in-depth examination of the healthcare aspect, which forms the foundation of the FragMont Project management system.

This section, like the territorial one, utilizes the information contained within the database, along with data gathered through the analyses conducted in the medical field. In this specific case, a research project was carried out with the aim of identifying the prevalent diseases in the Italian Alpine region. This study would, therefore, allow for the definition of what is meant by a "fragile subject" by integrating the data contained in the database, as well as providing insights into the socio-economic characteristics of the territory. Examples of these characteristics include the population density of the examined municipal area and the relationship between the population density and the presence of healthcare facilities in the municipality's region.

The ultimate goal of this research activity is to provide the Municipality with the necessary tools to determine, based on the distribution of diseases within the territory, the total cost of the modular telemedicine system. This assessment aims to establish the economic feasibility of adopting the telemedicine system, without the strictly territorial and geographical aspects influencing these evaluations.

A preliminary observation reveals that the medical section appears to be more complex compared to the geographical one, as the variety of situations considered in relation to the individual and the specific conditions of the telemedicine system can vary significantly. The following paragraphs will serve to analyze each step in detail for reading the decision tree in the medical section.

10.11 Mountain Municipality and Marginal Municipality

As previously discussed, the definition of "Mountain Municipality" contained within the database plays a crucial role in the FragMont Project. It allows for the identification of the number of fragile individuals residing within the municipal territory by cross-referencing existing data. This information is essential for subsequent analyses aimed at defining the specific characteristics of fragile individuals, whether they are elderly or have chronic illnesses. In the structuring of the decision tree, a connection has been established between these two areas of evaluation to facilitate communication between the two types of analyses.

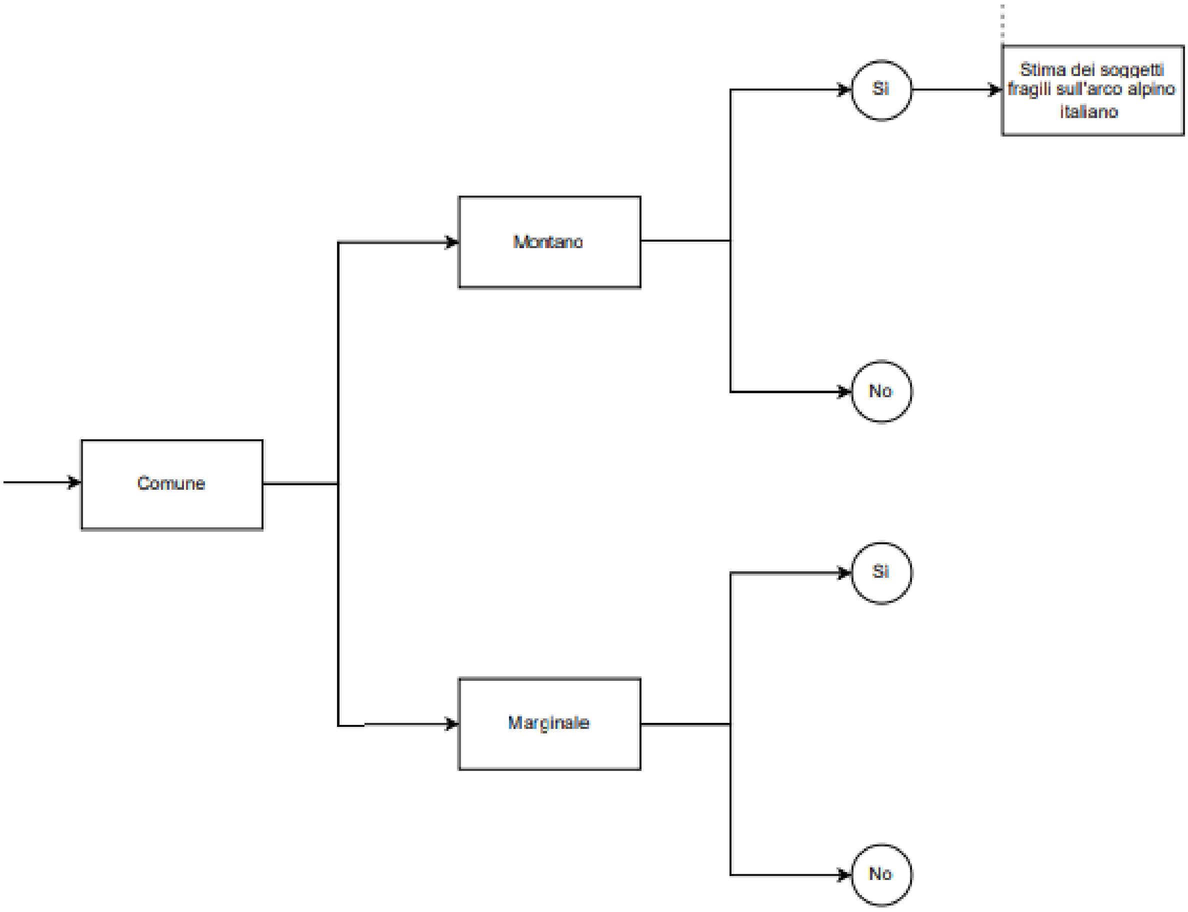

Figure 38: Definition of Mountain Municipality and Marginal Municipality

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10.12 Definition of a fragile citizen

As previously discussed in relation to the territorial part of the decision tree, once the name of the municipality under study is selected (Fig. 1), the Database allows for the automatic extraction of all socio-economic information that can help define and thoroughly understand the context in which the public decision-maker operates when implementing a telemedicine system. In fact, even before defining the characteristics of a fragile individual, the objective of the decision tree is to study the characteristics of the entire population of the municipality being examined.

Once the scope is established, the administration will proceed with the compilation of two databases: one related to the residence of the elderly population and another for those affected by chronic illnesses within the municipal territory. This geographical element, in parallel with what has already been studied regarding the territorial context, aims, in the final part of the FragMont Project study, to overlap the obtained information and define areas of risk/vulnerability within the municipality. Such information, always accompanied by economic data, will allow for the evaluation of priority scales for implementing interventions through a cost-benefit analysis.

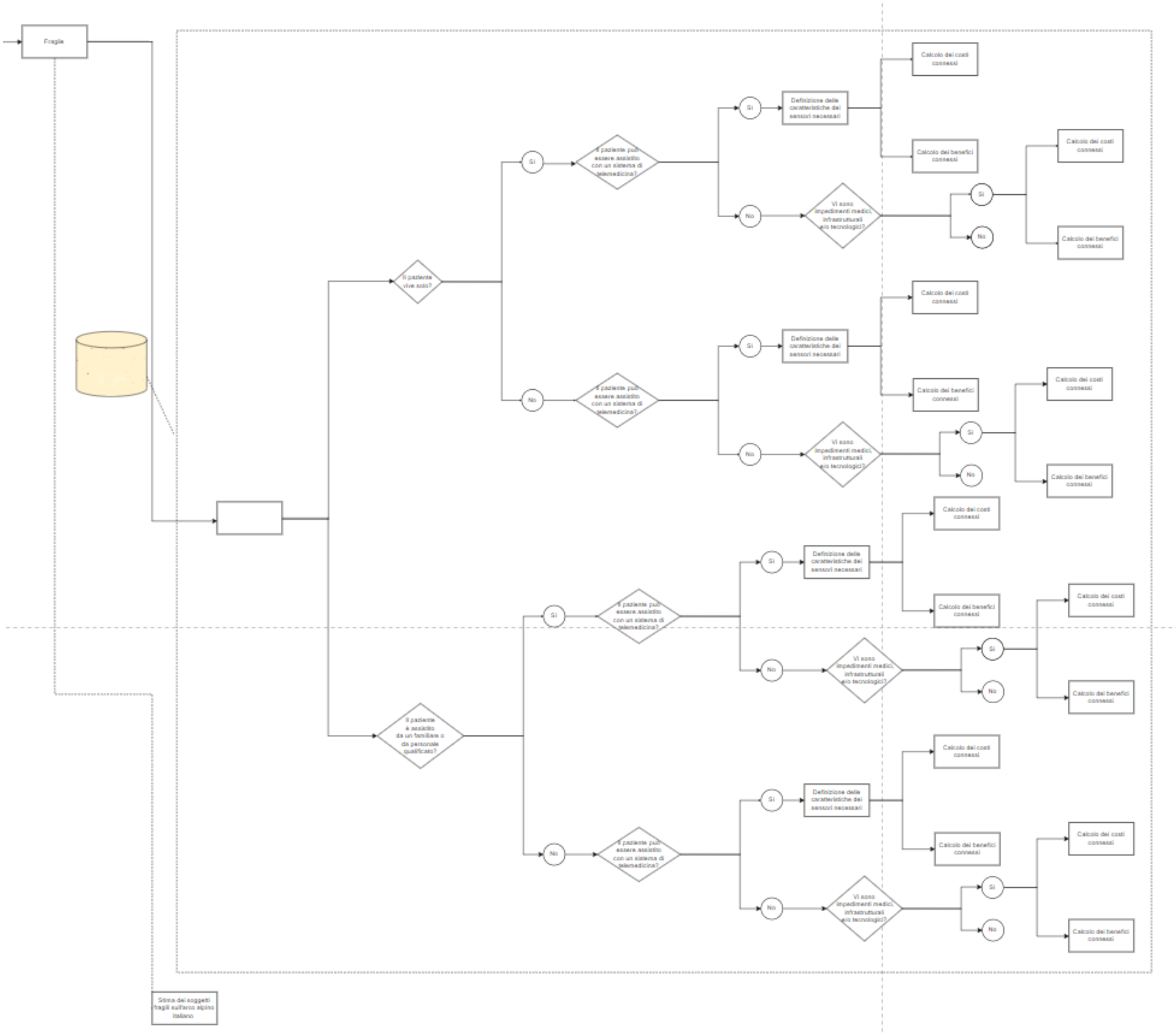

Figure 39: Creation of databases for the residences of fragile individuals living within the municipal territory

To guide the public decision-maker in identifying fragile individuals within the municipality, the two databases require, for each selected individual, answers to questions aimed at defining their socio-housing condition rather than their medical condition:

- Does the patient live alone?
- Is the patient assisted by a family member or qualified personnel?
- Can the patient be assisted with a telemedicine system?
- If not, are there any medical, infrastructural, or technological impediments?

This approach allows for an assessment of the level of vulnerability in which the individual lives, and based on that, defining the costs and benefits to be included in the final economic evaluation. The patient's clinical profile, a fundamental piece of information for the physician, will also be linked to this, considering the progression of the patient's illnesses, such as recent onset, long-standing conditions, stability, exacerbation, etc.

10.13 Structuring the telemedicine system

Starting from the analyses of the population's health status and related pathologies, research work has focused on the identification and the sourcing of specific sensor needed to implement the telemedicine system, which was developed in this phase of the project.

These sensors have been selected to monitor five general medical parameters, which are:

- Body temperature
- Oxygen saturation
- Blood pressure
- Body weight
- Blood glucose
- Heart rate

Alongside the telemedicine system, there is another existing and functional monitoring and surveillance system for the elderly, whose costs are known in detail. This system is developed to verify the regularity with which elderly individuals without specific pathologies perform their daily actions within their homes. The system considers parameters such as indoor air quality and temperature, evaluating them based on the habits of the elderly individuals. For example, it considers how much time the subjects spend lying on the couch. Its purpose is to detect anomalies within the elderly person's home and alert the appropriate authorities in case of irregular situations. Within the FragMont Project, the goal is to connect these two analyses to ensure effective and comprehensive monitoring of the individual in question.

In the modular definition of the telemedicine system, two significant limitations must be considered: the economic availability of the purchasing municipality and the technological skills of the predominantly elderly population to whom the telemedicine system is targeted. For the latter reason, the system design must have a user-friendly interface that allows for local data storage. Based on these premises, a subset of sensors has been selected to form the totem.

During the sensor selection and sourcing phase, various devices dedicated to monitoring the same parameters were purchased. This choice was driven by the desire to build multiple telemedicine systems simultaneously, with the practical aim of deploying multiple units in the field and obtaining real-world application of the system and, therefore, more feedback.

Indeed, just as in the territorial scope, simulations, tests, and verifications of the system will also be conducted in the medical domain. The next phase of the FragMont Project involves identifying a group of fragile individuals in the two pilot municipalities who are willing to install sensor systems in their homes for a certain period of time. This will allow for the monitoring of the aforementioned parameters and their regular communication to the primary care physician. The usefulness of the telemedicine system will be demonstrated in its ability to manage ordinary situations remotely in marginal areas, without requiring the physical presence of doctors and nurses. Therefore, from an economic standpoint, this aspect will be analyzed by comparing the avoided costs associated with physical travel between sites to the benefits offered by parameter monitoring through sensors.

To this end, greater collaboration will be required from the Local Health Authorities (ASL) to determine how often, in ordinary situations, individual patients physically visit their primary care physician's office. This will enable a comparison of the costs that would be incurred if the person were remotely monitored.

The benefits associated with telemedicine arise from continuous patient monitoring even in the absence of physicians, resulting in cost reductions for the travel that healthcare personnel operating in large areas must undertake. This situation can arise in mountainous contexts, where doctors oversee multiple municipal territories simultaneously. Traveling from one location to another consumes time and energy that could be dedicated to home visits and/or outpatient visits. Furthermore, the added value of the telemedicine system lies in the creation of a communication channel with the elderly individual that would otherwise be difficult to establish, thereby potentially preventing a deterioration in their health due to their isolated and unsupported condition.

The inconvenience caused by distance from urban centers not only affects healthcare personnel but also requires the patient and their family to travel every day, resulting in significant economic and time expenses.

The FragMont Project aims to develop telemedicine tools with the intention of providing support to doctors and patients in an ordinary context, without considering the possibility of extreme events occurring and the repercussions they could have on the constant observation of fragile patients. The emergency in a mountainous context refers to the lack of doctors in mountain areas, regardless of the risk of natural events and related hydrological risks. Therefore, the telemedicine system integrates with the sensor system to monitor the development of territorial stability from an economic perspective but remains independent from it.

The cost of the telemedicine system, on the other hand, will not only involve the expenditure incurred for the purchase of sensors but also all the costs associated with the design of the software and the system itself, as well as the time and expertise of those involved in its development.

10.14 Existing telemedicine system

Returning to the analysis of the decision tree, it has been observed that a significant portion of the socio-economic section is focused on investigating the conditions that can enable the implementation of a telemedicine system. To ensure that this occurs correctly, it has been deemed useful in this context to conduct a survey of the initiatives already in place within the municipal territory.

Similarly to the territorial case, it could happen that telemedicine-related tools have already been installed within the municipal boundaries. In order to map the risk and vulnerability situations of fragile individuals, it is then essential to build archives related to these critical situations, providing an overview of the current state of healthcare management for the resident population.

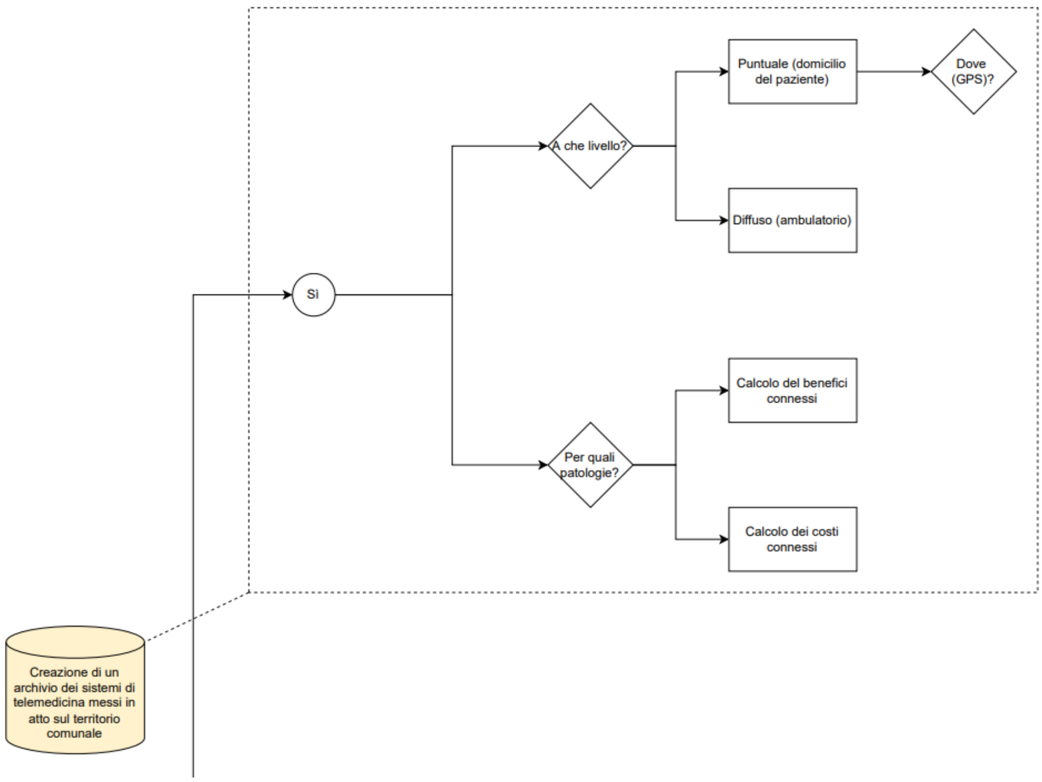

Figure 40: Creation of archives for residences of fragile individuals where telemedicine systems have been implemented

10.15 Prototype telemedicine system

Proceeding with an investigation aimed at understanding the potential scope of action for the public decision-maker, this section of the decision tree takes on a very detailed form, leading to the economic evaluation of costs and benefits associated with the tools to be employed for telemedicine in any examined situation.

In relation to this archive, another question is posed to the administration, namely "Is it worthwhile to enhance the telemedicine system?".

Indeed, the construction of the aforementioned archive does not represent the end of the decision tree associated with an economic evaluation, but rather the basis for further considerations to be carried out. If such tools have not been employed, the question to be answered would instead be "Is it worthwhile to implement a telemedicine system?"

The structure of the decision tree following these two questions assumes an almost identical form. In both cases, the cost-benefit analysis aims to evaluate every possible situation, which is why, for the first time within the decision tree, the interpretation of the telemedicine system is divided into ordinary conditions and emergency conditions for the patient.

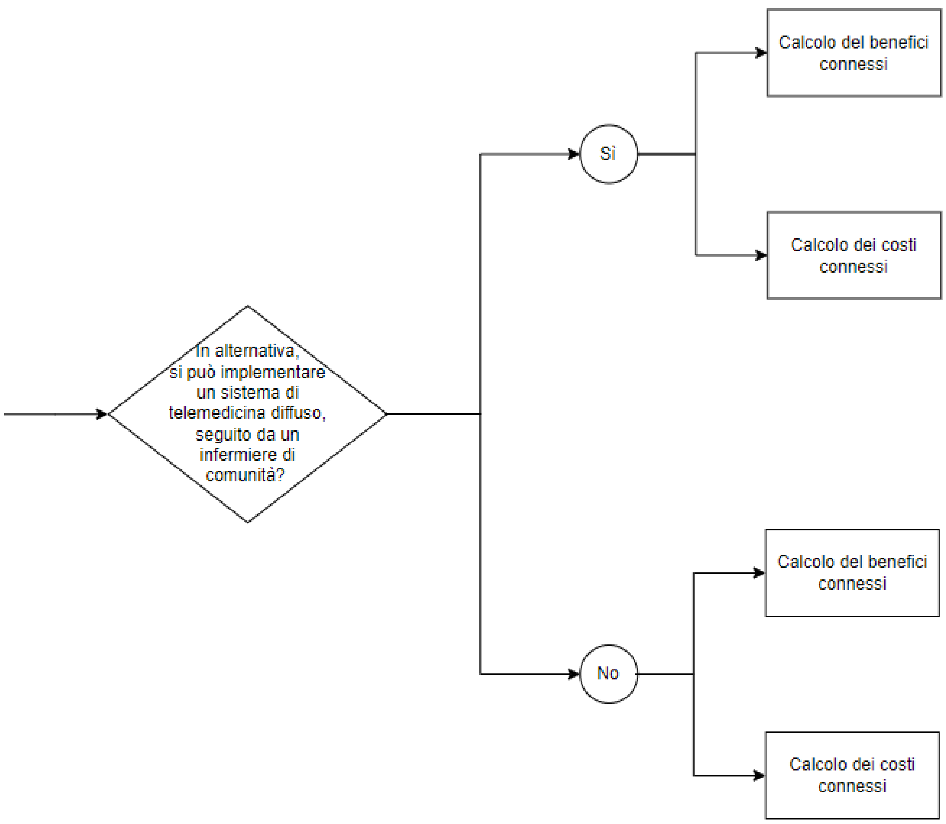

Figure 41: Evaluation of the impact of natural events on telemedicine

Subsequently, for both hypotheses, two more other questions are set. They have a completely different nature but answering to them provides useful indications to complete the mosaic of information needed. The first question posed to the administration is "Can the system be affected by the occurrence of an extreme event?”.

As extensively argued above, in order for telemedicine to provide an advantage to the population, it must be able to withstand severe hydrological disasters. However, it is also important to consider the hypothesis in which an event interferes with the telemedicine system, in order to have a clear understanding of all the associated costs.

The other question takes a completely different approach and asks the public decision-maker about the possibility of implementing a hybrid approach to telemedicine, or rather a "distributed telemedicine system". Among the various hypotheses to propose and that the administration could consider, one is not to provide comprehensive assistance to isolated and fragile patients who need to be monitored through telemedicine but to organize a "rotation" system managed and taken care of by the community nurse.

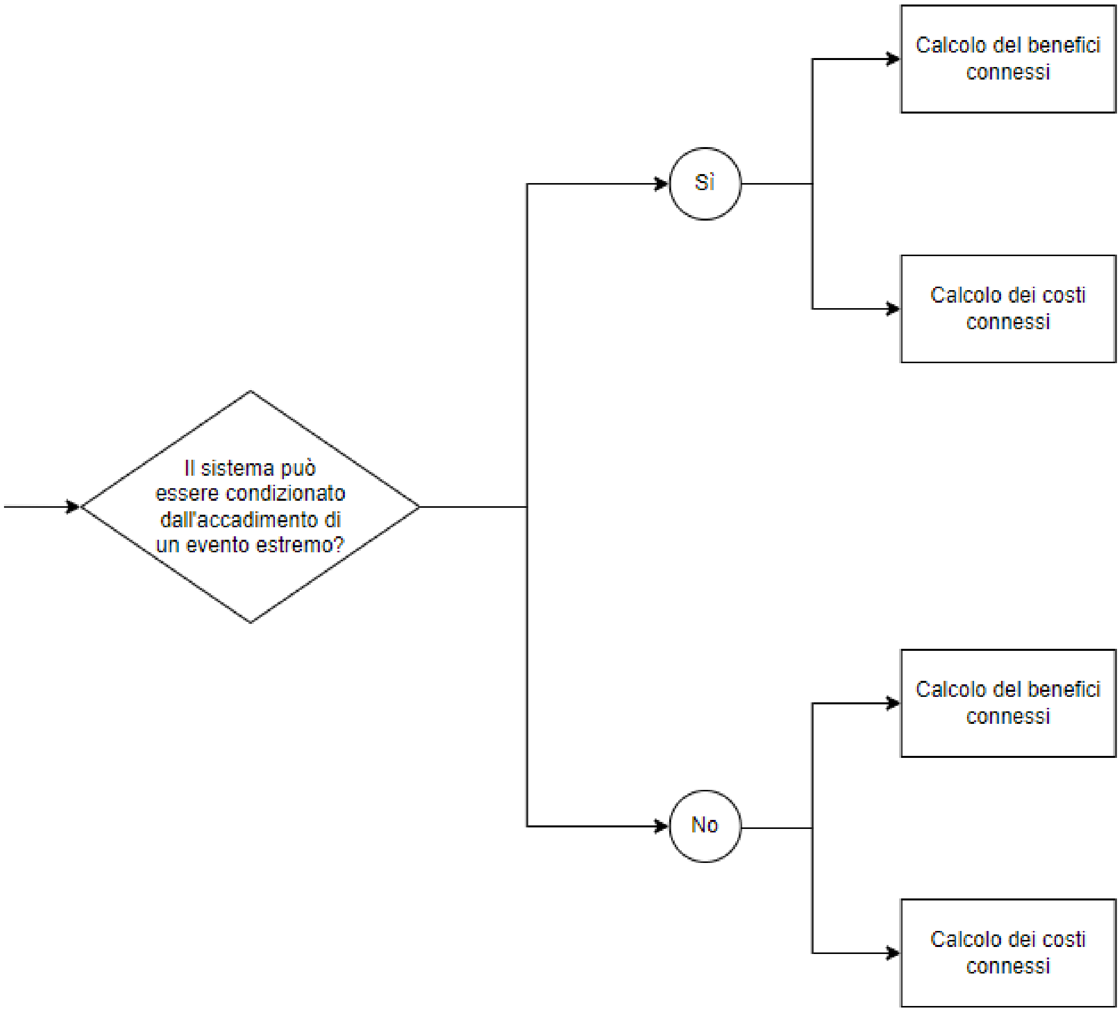

Figure 42: Evaluation of the possibility of implementing a distributed telemedicine system

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This would allow for the evaluation of every possible situation, considering:

- Total absence of telemedicine systems;
- Total presence of telemedicine systems;
- Partial assistance thanks to the use of telemedicine systems.

The last option plays a crucial role because it presents a concrete alternative in the absence of adequate funds for the implementation of a full-fledged telemedicine system. The distributed telemedicine service would, in fact, help alleviate the financial burden on the municipality's budget while providing a fundamental service to mountain communities.

In this care scenario, the community nurse would have the opportunity to concurrently follow a greater number of patients, even if they are geographically distant from each other. The decisive element in choosing this alternative is therefore the territorial extension of the municipality in question: if the distances are such that continuous assistance from the nurse is not feasible, despite their ability to take measurements and communicate them to the doctor, a support tool becomes useful in reducing economic and time losses. The same energy, in fact, could be used to follow and visit other patients, perhaps less fragile but still in need of assistance.

Given these premises, one could argue about the usefulness of the telemedicine system since the community nurse should not require this type of technological support to measure and communicate the patient's parameters to the doctor. Indeed, the telemedicine system would be needed when the patient does not have their means to communicate with the doctor and can only do so with the support of qualified professionals. In such a case, the administration may inevitably consider not acquiring such equipment.

On the other hand, implementing a distributed telemedicine system could become an interesting marketing hypothesis for municipalities located in tourist areas, such as in the case of Alagna Valsesia. The municipality could offer an additional service for elderly tourists who would have the possibility, if necessary, to monitor and communicate their parameters to the reference doctor, even if they operate in areas far from the site in question. For this reason, tourist flows in relation to the resident population within the municipality become decisive factors to consider when deciding whether or not to implement a telemedicine system.

10.16 Economic evaluation associated with territorial and healthcare interventions

The discussion thus far has described in detail the utility associated with the implementation of a telemedicine system and sensors for monitoring the municipal territory, aimed at combating the effects of extreme natural events. The focus now shifts to the economic evaluation of these tools, namely the cost-benefit analysis associated with their activation to mitigate territorial vulnerabilities.

Indeed, economic language is the only one capable of supporting the municipal administration in defining a priority scale for investments to be made within its territory, whether they are related to healthcare needs or connected to hydrogeological disaster prevention.

For this reason, the structure of the decision tree has been designed to converge the two lines of activity towards an integrated technical and economic evaluation of the population monitoring system and the solutions applied for territorial fragility. These evaluations will subsequently converge into an integrated management system for fragility in mountain areas, as initially envisioned by the FragMont Project.

10.17 Overlap of economic and territorial data

As emerged during the review of the decision tree and as discussed in this report, even the geographic coordinates associated with any potentially vulnerable location from a territorial perspective, and/or related to situations of fragility for the resident population, appear decisive in selecting the choices that the municipal administration can make to prioritize investments on its territory.

This highlights the need to integrate the economic evaluation of interventions to be carried out with the localization of fragile individuals and territorial vulnerabilities. For example, if there is only one road to reach a location where a person with serious illnesses lives, resolving the problem would become a priority in the event of road interruption due to a landslide. However, if the location is accessible via multiple routes, then the resolution of the problem would be less demanding and urgent, and it could depend on the evaluation of multiple, possibly different, options.

In this perspective, the archives related to health fragilities that the municipality must produce, along with their associated costs and benefits, as well as the GPS coordinates of the residences of fragile individuals, acquire central importance. Overlapping the geographic coordinates of sites where fragile individuals live with those of areas susceptible to extreme natural events allows for comparing the costs to be incurred in that specific location to prevent territorial risks along with the costs of caring for the fragile individual.

During the revision phases of the decision tree, an idea emerged to make the integration of these geographic data visible and easily understandable: the development of a GIS mapping of the municipal territory. Such a mapping could immediately show the overlap of areas subject to natural hazards with the locations where fragile individuals reside. This easily readable tool would be a valuable support for the decision-making process that the public decision-maker should undertake.

The link between the territorial and medical domains will ultimately be established through the economic evaluation, which relates to the expenses to be borne by the municipal administration and represents the synthesis of all cost items analyzed during the drafting of the decision tree in both its sections.

10.18 Accessibility of the system

The two lines of activity represented by the decision tree diagram can be graphically represented in various ways, through a series of screens that present the situations (questions and answers) to be addressed sequentially. The typical user could be a municipal official, someone who is familiar with computers. The decision support tool is designed to be operational, so in the prototypical phase, graphical and purely aesthetic aspects are reduced.

The telemedicine model installed at the homes of the elderly requires considerable attention regarding graphical and operational aspects. In this case, the issue of system accessibility is a priority. The concept of user-friendliness needs to be carefully explored, particularly regarding the sensory and motor difficulties that elderly users may experience.
Various considerations have been made in this regard during the prototype construction, and attention has been given to the legibility of commands and ease of understanding.

However, it is evident that during the refinement phase of the pre-industrialization prototype, crucial aspects need to be addressed and resolved, considering the most frequent situations and investigating the ways in which they have been resolved.

Furthermore, different situations (patient alone or with assistance) may lead to different specifications. The proposal resulting from the project focuses on the potentially critical condition of a fragile patient accessing and operating the system alone. However, in the majority of cases, fragile patients receive assistance, even continuous support, from caregivers or family members. Nevertheless, an easily accessible system in terms of user-friendliness could still accelerate the sharing of an emergency situation and the intervention of relevant individuals.

Conclusions

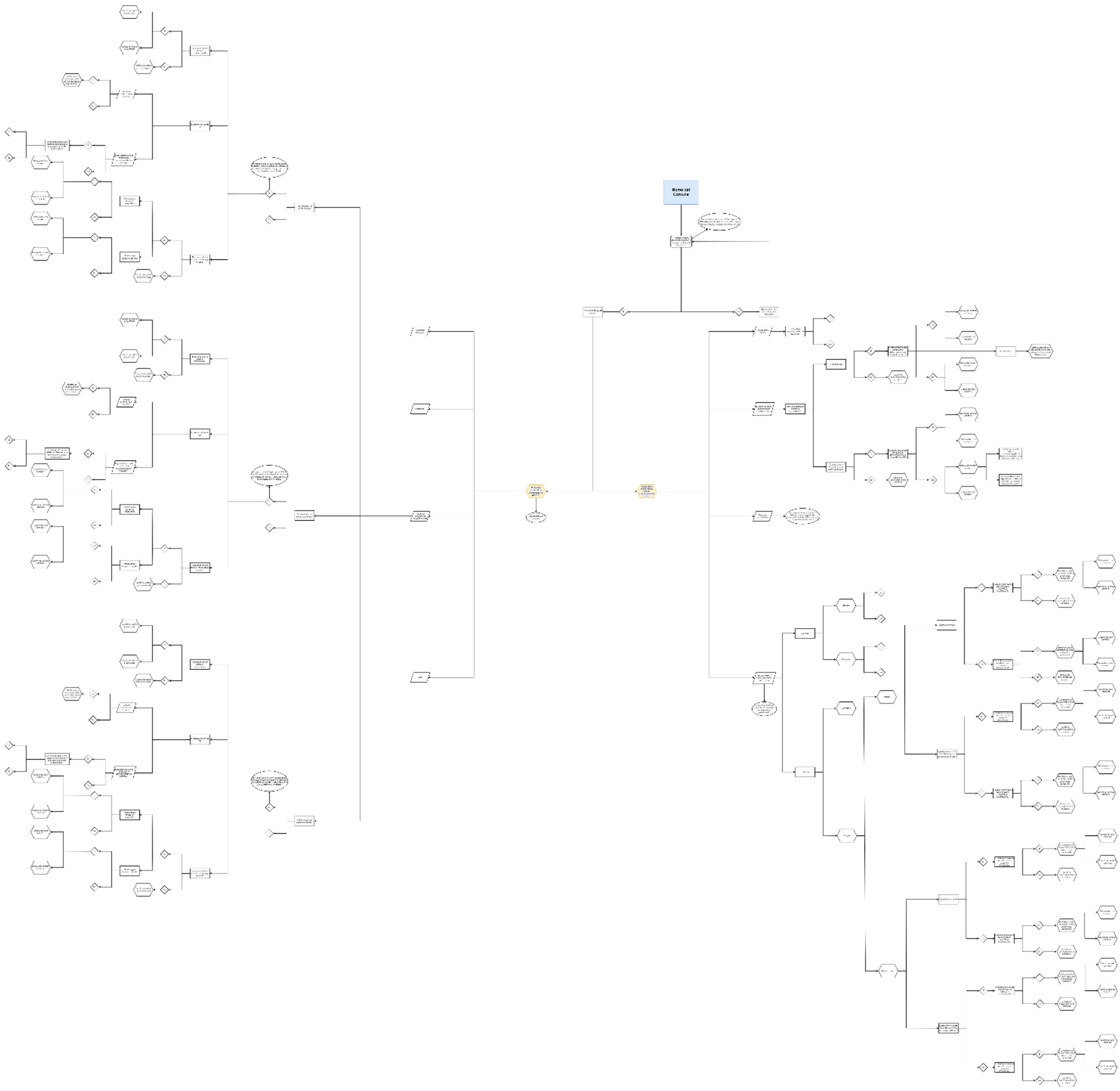

Figure 43: Decision Tree Structure

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The FragMont project was born from the expertise acquired in mountainous areas, enhanced by advancements in the realm of Internet of Things (IoT) and Artificial Intelligence (AI) applications. The project's unique approach, characterized by a multidisciplinary framework, has been pivotal since its inception, resulting in the creation of a Decision Support System that effectively tackles contemporary challenges.

The significance of these challenges has been amplified by the prospects offered by the National Recovery and Resilience Plan. The regular updates on the vulnerability of the land to hydrogeological instability have almost become a regular occurrence. This issue, due to its widespread impact on various regions of Italy, affects the population and hampers territorial progress, garnering attention on online platforms as well as radio and television broadcasts. References can be found in the April 15 broadcast of Radio RAI 1 at 9 o'clock.

The issue of depopulation in mountainous regions and its consequent marginalization have consistently drawn attention and garnered substantial contributions from esteemed organizations like CIPRA and UNCEM. Notably, references can be found, particularly concerning strategic initiatives. UNCEM is actively involved in guiding the mountain and inland areas' strategies, whereas CIPRA undertakes political endeavors backed by scientific evidence, with the goal of bringing marginalized regions to the forefront of political agendas.

The NODES project - Nord Ovest Digitale E Sostenibile (Northwest Digital and Sustainable) - the innovation ecosystem funded by the Ministry of University and Research (MUR) within the framework of the National Recovery and Resilience Plan (Decree No. 1054 of June 23, 2022), in which the University of Turin (UniTo) is a founding partner, creates research and industrial value chains in seven sectors (Spokes). Among these, the Digital and Sustainable Mountain and Health Industry and Silver Economy sectors appear to be the most relevant for the evolution of FragMont. The opening of calls for proposals for Industrial and Academic Proof of Concept represents an opportunity for companies that wish to propose industrial research and experimental development projects, as well as for researchers who submit proposals consistent with the research and innovation themes of the various spokes. In Spoke 4, participatory regeneration of mountain territories in the context of tourism, environmental protection, and climate risk management are topics addressed in the territorial part of FragMont. In Spoke 5, the management of territorial medicine and the preventive, diagnostic, therapeutic, and rehabilitative aspects pertain to the medical part of FragMont.

It is believed that both collaboration with companies and the direct involvement of FragMont researchers are fields to explore in order to make the Decision Support System functional in defining strategies for sustainable development and to correct the shortsightedness that has characterized the consideration of mountainous territories.

In summary, the series of questions and answers that schematically summarize the theme of the fragility of mountainous areas and guide strategic decisions could be the following:

1. **What are the key factors contributing to the fragility of mountainous and hilly territories in Italy, particularly in Piedmont?** Factors contributing to the fragility of mountainous and hilly territories could include geological characteristics, climate change, improper resource use, and neglect of territories.

2. **How does the increased frequency and intensity of natural disasters, such as landslides, impact these territories and their populations?** Increased natural disasters could lead to loss of life, property damage, disruption of local economies, and displacement of populations.

3. **How do climate change, improper use of resources, and neglect of territories exacerbate the natural imbalances in these areas?** Climate change might exacerbate natural imbalances by increasing the frequency and intensity of extreme weather events. Improper resource use and neglect of territories could lead to environmental degradation, making these areas more vulnerable to natural disasters. This means that climate change impacts are worsened by the lack of an effective territorial management (i.e., improper mitigation strategies or monitoring system).

4. **What are the economic, social, health, and cultural impacts of these phenomena on the territories and their populations, both in the short and long term?** The impacts of these phenomena could include economic losses due to property damage and disruption of local economies, social impacts such as displacement and trauma, health impacts from injuries or lack of access to healthcare, and cultural impacts if important cultural sites or practices are disrupted.

5. **How does the demographic shift towards an aging population in these areas contribute to their fragility?** An aging population could contribute to fragility by reducing the workforce and increasing the demand for healthcare and social services. This could be exacerbated if younger people continue to leave these areas.

6. **What are the implications of the growing trend of chronic diseases, particularly in the context of an aging population in these territories?** The growing trend of chronic diseases could put additional strain on healthcare systems, particularly in areas with an aging population. This could also lead to increased healthcare costs and reduced quality of life for individuals with these conditions.

7. **How does the demographic disproportion of mountain and hill areas intensify the conditions of fragility of the population, particularly in relation to access to healthcare facilities?** Demographic disproportion could intensify fragility by reducing the availability of healthcare and other services in these areas. This could lead to increased travel times for healthcare, which could be particularly problematic for older individuals or those with chronic conditions.

8. **How can open-source technologies such as Arduino e Raspberry PI’s be helpful in natural risk prevention and monitoring, and in fragile population caring?** Open-source technologies like Arduino and Raspberry Pi’s empower communities, researchers, and healthcare providers with versatile, cost-effective, and highly customizable tools to address the unique challenges of natural risk monitoring and the care of fragile populations. These technologies are catalysts for enhanced safety, well-being, and community resilience.

9. **What are the economic implications of implementing preventive interventions and/or managing environmental or health risk situations in these territories?** The economic implications of preventive interventions could include the costs of implementing these interventions, as well as potential savings from reduced property damage, healthcare costs, and other impacts of natural disasters. These could be weighed against potential revenues from increased tourism or other economic activities.

10. **How can revenues be derived from enhancing the attractiveness of these locations, for example, through the provision of telemedicine services or systems supporting the securing of the territory?** Potential revenues could come from increased tourism if these areas are made safer and more attractive to visitors. This could include revenues from lodging, dining, and other tourist activities, as well as potential increases in property values.

11. **What are the potential scenarios for planning and managing the territory based on the protection objectives considered as priorities?** Potential scenarios for planning and managing the territory could include different combinations of preventive interventions, resource management strategies, and economic development activities. These could be evaluated based on their potential costs, benefits, and impacts on the fragility of these areas.

Authors

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