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MODELLING OF ENVIRONMENTAL AND ECONOMIC COSTS AND BENEFITS OF THE MANAGEMENT OF THE MOUNTAIN HUTS IN AOSTA VALLEY – ITALY

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Abstract

Management of mountain huts is inserted in a particularly fragile ecosystem, i.e. the mountains, to which they are linked by a relationship of mutual interdependence. As a business activity, the mountain hut interacts with the surrounding environment, and in doing so, generates inevitable impacts on this. As regards the public administration, the mountain hut category may represent a potential recipient of resources to the extent that it decides to encourage application of measures able to mitigate such impacts. This work describes a system of modelling the mountain hut activity at a double scale. The first describes the processes of the activity of each mountain hut and the relationships between these and protection of the surrounding environment, while the second level aggregates the individual models of 35 mountain huts of the Aosta Valley and describes system behaviour according to various strategies at aggregate level. The final aim is to establish, where sufficient quantitative data is available, a definition of costs and benefits such as to permit economic and environmental assessment of a suite of management and technological strategies at the level of each mountain hut or at aggregate level.

Keywords: Mountain, sustainable tourism, STELLA® language 9.0, public investments, accommodation facilities, renewable energy.

Introduction

The aim of this work is to establish a methodology to evaluate costs and benefits depending on choises adopted to improve the environmental impact of a mountain hut. In addition to the single hut level, the methodology must be capable of aggregating the results of independent individual choices in order to describe the effects as a whole, due to the behaviour of the mountain huts of the Aosta Valley. While the set up of the methodology has been made counting on the experience gained through several research projects on field, its development – at single and aggregate levels – has been possible by the application of the STELLA® language.

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Infact, generally modelling illustrates the behaviour of a system and, to do this, considers the most significant variables, highlighting the relationships between these in terms of direction and intensity. The STELLA® language has been designed to develop and deploy the ability to understand how a system works through the construction of models using "user-friendly" display tools.

Systemic logic can also be applied to management of the mountain hut and, in particular, of the related environmental aspects; in particular, in view of the typical characteristic location of this type of structure, there is a close correlation between the various characteristic phases of procurement, transformation and disposal of resources. At the same time, at aggregate level, the set of mountain huts interacts with a mountain system with which it is closely connected in a relationship of mutual interdependence.

Modelling of the management of the mountain huts of the Aosta Valley pursues two main objectives, tied respectively to a macro and micro economic vision of the mountain hut.

The first, of a **general** character, aims to describe the overall environmental impact of the aggregate of mountain huts taking into account that "*no complete bibliography on this subject exists, [...]; therefore, it is difficult to quantify the environmental impacts of mountain accommodation structures with any degree of precision*". Quantification of environmental aspects is a "*sine qua non for verifying the areas and margins of improvement and for planning actions in this direction in order to achieve a correct compromise between development of tourism and preservation of natural heritage*" (Beltramo et al., 2006a). A quantification of this type is essential in guiding the policies of the public administration whose functions also include identification of incentives directed towards improving management of environmental aspects and of the impacts of anthropic activities in the territory, also including therefore mountain huts. An appropriate costs-benefits evaluation based on analysis of the effective situation is an essential condition in order to define a truly functional set of incentives able to promote optimised distribution of resources, to avoid indiscriminate investments and to maximise the results achieved in terms of reduction of environmental spillover.

The second objective, of a more **particular** nature, refers to the dimension of the single mountain hut. Using the simulation program, the manager can verify the effects of his/her decisions (such as replacement of conventional technologies with eco-efficient technologies or modification of some management strategies) on various aspects of management, with consequent repercussions both from an economic view and as regards the environmental profile of the structure. Therefore, the manager can select the solution considered most satisfactory. The final goal is insertion of the "environmental parameter", accompanied by an economic type assessment of how this has been taken into account, amongst the characteristic parameters of management strategies.

Basic assumptions of the model

Management of the mountain hut

"*[...] the mountain hut is a place of transformations. These include chemical, physical, chemical-physical transformations of natural resources, raw materials, energy which are combined to comply with the needs expressed by guests*" (Beltramo, 2006b).

According to the above, it is possible to display, via a diagram (Fig. 1, Beltramo et Cuzzolin, 2001) the incoming flows (inputs) to the processes that are necessary to guarantee the mountain hut service, in order to meet guests' requirements, and the outgoing flows (outputs) generated by these.

The activities are carried out according to a set of legal constraints.

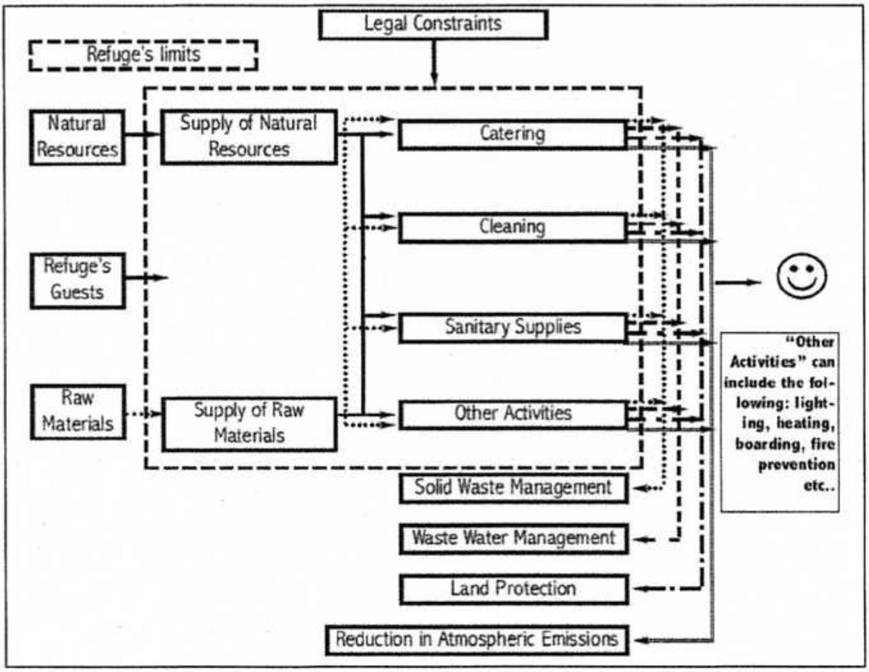

Fig. 1 - Identification of the individual process phases in the activities of a mountain hut.

As Alpine accommodation structures are inserted in a very fragile environment, their impacts on the environment are particularly significant. Therefore, if one of the aims of the activity is satisfaction of the guests, there are also concurrent environmental outputs that should be accompanied by actions directed towards minimizing these, so that the underlying assumptions of the activity of the mountain hut, i.e. its location in an uncontaminated environment, are preserved in the long term.

The STELLA® environment makes it possible to describe the functioning of the characteristic processes of the activity of the mountain hut, highlighting the various relationships between these, and to simulate the behaviour of the related environmental variables. It is also possible to highlight the way in which modification of technological equipment and methods of management affects environmental and economic performance.

Aggregating the individual components, it is then possible to highlight the behaviour of the system, including in the simulation the importance of decisions at macroeconomic level.

Distribution of overnight stays

To determine the dynamics of the main characteristic processes of mountain hut activity, the influx of arrivals has been identified as a determining element. It was necessary therefore to define hypotheses according to which the data available for the study, consisting of the data of overnight stays aggregated by Valley (Aosta Valley Tourist Office, 2004), can be attributed to the individual mountain huts. The attribution of overnight stays therefore depended on the period during which each mountain hut is open, assuming a greater influx at mountain huts open for a higher number of months and taking into account seasonal nature of the influx of arrivals, which are not distributed evenly throughout the year but characterised by peaks during certain periods. In particular, when considering the same month, the irregular nature of arrivals has been taken into account. The weeks corresponding to holidays (for example Christmas, Easter holidays or the August Bank Holiday week) are characterised by peaks in the number of persons in transit and of overnight stays at the mountain hut. In order to distribute the number of overnight stays attributed to the mountain hut in relation to the months during which this is open, this figure has been allocated through weighting on a monthly and weekly basis.

The coefficients identified at monthly level were based on identification of four types of mountain hut:
category 1: open only in the Summer, from June to September, with a peak in the months of July and August;
category 2: with the same trend of visitors as for the previous category but concentrated in a shorter period of time (only July and August);
category 3: mountain huts open for the Alpine skiing season, characterised by an initial peak close to high season, in particular in March and April, followed by a slight decline shortly before the start of the Summer and a further upswing according to trend described for category 1;
category 4: mountain huts open not only in the Summer but which, according to

location, are accessible for most of the year with two main seasons, one Summer and one Winter.

Figure 2 shows the trends of the weighting coefficients adopted.

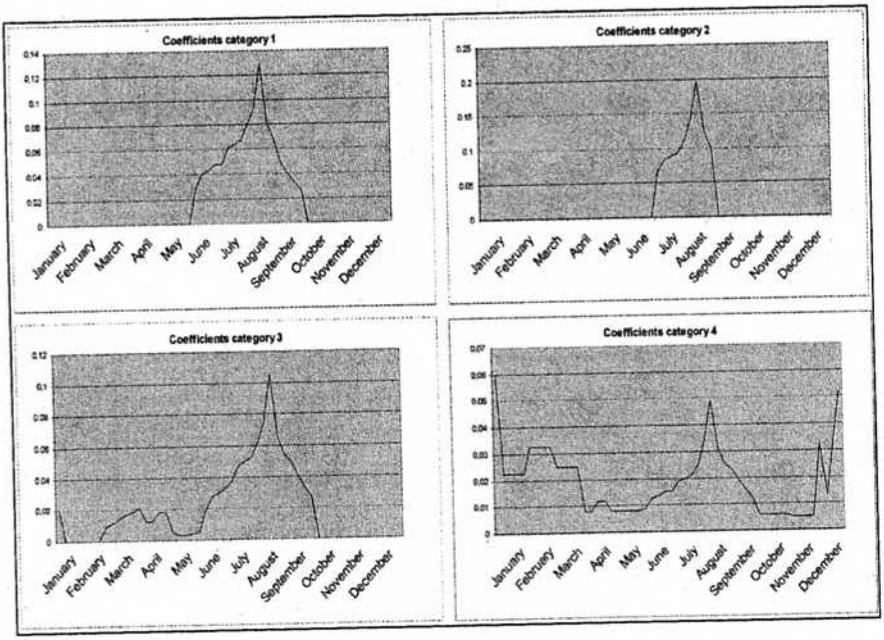

Fig. 2 - Distribution of overnight stays at the mountain hut: possible types.

Technological and management characteristics of the reference sample

The model has been constructed using information regarding 35 of the 53 mountain huts of the Aosta Valley; this is the number of structures for which, following a survey (Beltramo et Duglio., 2006c), it has been possible to record information regarding equipment and main methods of management. In particular, information was recorded regarding methods of procurement of water, the treatment of waste water, the production of electrical and thermal energy, the transport of materials and management of waste. This information was very important in effectively defining the main problems tied to management of the mountain hut and, in particular, information regarding the types of energy production plants (Fig. 3) was inserted in the model.

Fig. 3 - Display of electrical energy sourcing technologies at mountain huts of the Aosta Valley – Italy.

The structure of the model by individual mountain hut

The model is structured at two levels; a first level that describes the typical processes of the activity of each mountain hut and a second based on aggregation of the individual models. Both levels are structured to carry out simulations in order to modify a number of basic variables.

The interface used to manage the simulations has been designed to permit divulgation. In fact, the model is not only directed to studying the problem but also towards creating an instrument that can be used by recipients, i.e. managers and the public administration. Briefly, the structure of the model by individual mountain hut is shown in Fig. 4.

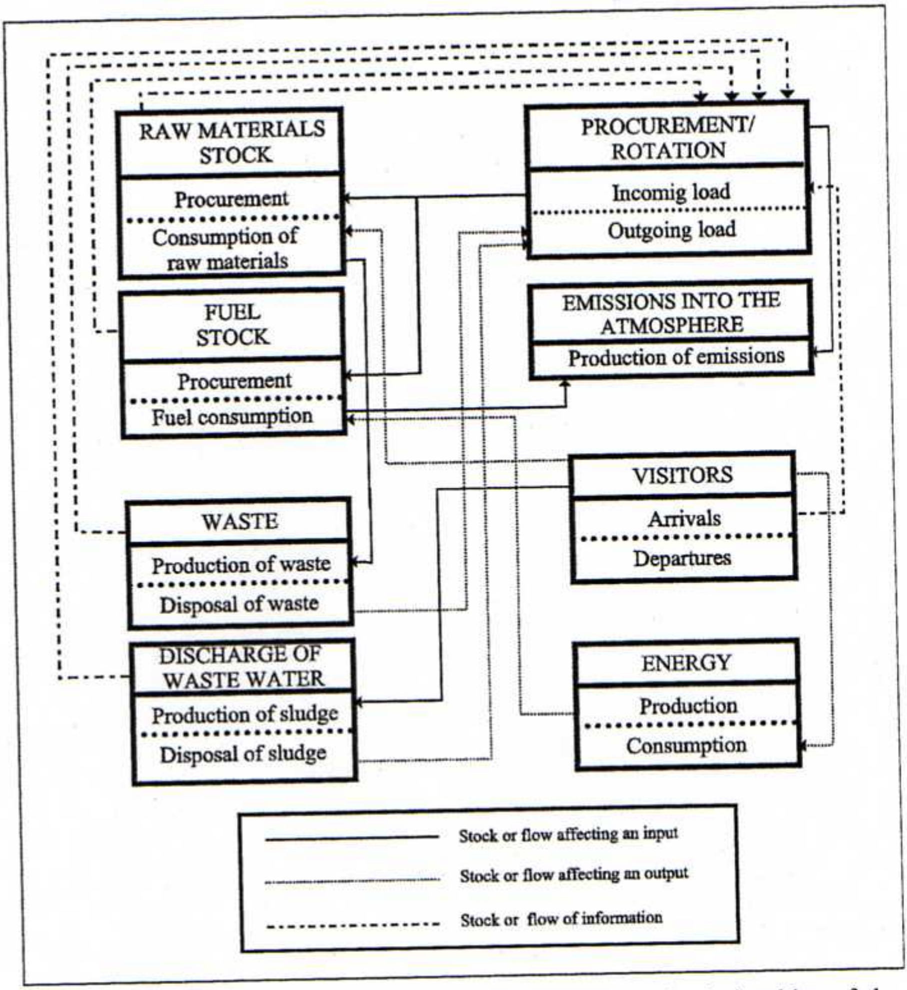

Fig. 4 - The mountain hut: summary of the elements and relationships of the model.

Each box of Fig. 4 represents a stock that forms the model; the incoming and outgoing flows that determine the entity of the stock have been indicated respectively inside this. These are in turn tied to the trend of other flows or stocks. The model has been formulated for 35 mountain huts. The underlying logic of the dynamics of the processes and the relationships between these are illustrated in detail below.

Overnight stays at the mountain hut

The model is structured so that, inserting a code corresponding to the category of the mountain hut considered and the estimated annual number of overnight stays, these are distributed automatically in time according to appropriate coefficients. In this first processing of the model, no distinction has been made between "arrivals" and "overnight stays" but it is assumed that incoming flows form the stock of "guests" who remain at the mountain hut for the time unit defined and who leave the mountain hut within the next time unit (departures), as illustrated in Table 1.

TABLE 1

CHANGE IN THE VALUES OF ACCESSES, OVERNIGHT STAYS AND DEPARTURES IN TIME T

Time	Accesses (input)	Visitors (stock)	Departures (output)
t_1	56	...	...
t_2	72	56	56
t_3	23	72	72
t_4	...	23	23

Reading these values from another point of view, it is possible to interpret the accesses as forecast overnight stays, which represent the stock that will determine, for example, consumption. The value of the accesses is an important data as regards the functioning of other variables, the determination of which is strictly linked to the forecast flows of guests (for example, stocks in store and, consequently, the need for procurement).

Storeroom

Management of the storeroom is an initial key aspect of mountain hut management. Due to the particular location of the mountain huts, methods of procurement are not always simple. In some cases, cars are used while, in others, goods are transported on foot or using helicopters. In each case, transportation capacity is limited and tied to the cost of this, especially when the helicopter is the only means available. Also, it must be considered that procurement does not refer only to consumables for guests but, according to the type of energy production, part of transportation capacity is absorbed by the need to equip the mountain hut with the necessary fuel. Also, selection of the quantities to be procured by the manager will vary according to expected inflows.

Limitations on load capacity, with regard to procurement, also apply to the unloading phase. For this reason, the manager tries combine unloading and loading in order to minimise transport requirements.

In the model formulated, the storeroom consists of two main parts:

- raw materials store;
- fuel store.

These are inversely proportional insofar as limitations exist on transportable load with rotation of procurement which must be divided between raw materials and fuel; the proportion depends on the importance, amongst the various sources of energy production, of the fuel-powered generator set (the more important the generator set, the higher the quota allocated to fuel). Where this is not present, a minimum level of fuel is considered necessary in any case for functioning of the mountain hut. A minimum level is also established for the raw materials store; this is inversely proportional to the level of accesses and the period of the year in order to cater to the need for sufficient stocks of consumables in periods of major influx and, at the same time, to avoid over procurement when, despite the high number of accesses, the season is drawing to a close. There is also an upward limit on both storerooms, i.e. it is assumed that procurement is carried out only up to a certain level, the threshold of which may be dictated by various reasons (such as, for example, limits of space). In this case also, it is assumed that there is an inverse relationship between the maximum level of stockable fuel and the related importance of any generator set.

In exit from the storeroom, the consumption of fuel is proportionate to effective use of the generator set, while consumption of raw materials depends on the number of persons present at the mountain hut, according to a per-capita consumption rate.

Procurement

Two methods of procurement are contemplated: by helicopter and using other methods of procurement for which types of transport may be used (car, snowmobile, cableway, etc.). In the simulation, rotation or procurement is carried out:

- in the opening week of the main season for the initial load;
- at the time of closing of the mountain hut (for transport of waste and any other material down the valley);
- when specific conditions occur, i.e. in the case in which:
- the level of one of the two stores drops below the minimum level defined, as described above;

- waste accumulated at the mountain hut exceeds the maximum permitted level;
- the maximum level of filling of the septic tank has been exceeded or the manager decides to empty the septic tank at the start of the season.

This latter condition applies only in the case of transport by helicopter as, if the mountain hut usually adopts other methods of procurement, it can be assumed that the carrier authorised to dispose of sludges has direct access to the mountain hut; therefore, rotations for this purpose are treated separately in the "other methods of transport" model. In the case of the helicopter, the sludges are aspired and loaded on the helicopter and transported down the valley where the authorised carrier is responsible for disposal of these. In both cases, the model counts the effective number of rotations.

Rotation or procurement produces inputs to and outputs from the mountain hut. A quantity of material corresponding to the maximum load capacity of the means of transport is transported to the mountain hut unless the mountain hut is to be closed in the short term and will therefore be only partially used. To this end, the model is designed to receive information regarding the moment (week) of opening and closing of the mountain hut. Load capacity will be spread between procurement of the raw materials store and of the fuel store, as mentioned above.

As regards unloading, the transportable quantity will be equal, at the most, to load capacity. This quantity will consist of waste or, in the case of transport by helicopter, of sludges.

Waste

In the model, the production of waste is represented by a percentage production of waste commensurate with the consumption of raw materials (outgoing flow of the raw materials store). These are accumulated until they are disposed of down the valley which, in the model, is carried out at the time of the rotation or procurement, when a specific level above which further waste cannot be accumulated is reached, or on closing of the season.

Production of waste water

Analysis of the technological and management characteristics of the sample examined revealed that the main method adopted to dispose of waste water is treatment using an Imhoff or septic tank. The model has therefore been structured to incorporate this information and differs slightly in cases in which the mountain hut is connected to the sewers (in which case there is no problem of disposing of residual sludges).

The production of sludges is quantified in both cases assuming a per-capita production rate, multiplied by the number of overnight stays.

The tank, where present, may be emptied when the sedimentation compartment is full or on opening of the season of the mountain hut, at the time of initial procurement.

Production of energy

Mountain hut energy production systems may vary considerably, in particular, according to available equipment which also has repercussions on other management components. For example, if energy is produced mainly by a generator set, this implies the need to procure fuel, affecting therefore also the store, as mentioned above.

The logic applied to describe the delicate topic of production of energy is the result of surveys of the plants installed at the mountain huts of the Aosta Valley (Beltramo et al., 2006a, Fig. 3). The model has been defined highlighting, in the energy sector, the potential presence of the fuel-powered generator set, of the hydroelectric power station and of the photovoltaic system. For each of these plants and for each mountain hut, the data relating to the power in kW of the plant owned has been inserted in the model. Given the potential energy that can be produced, the effective energy produced depends on the significance of each plant for the mountain hut, which can be summed up with a value from 0 to 1, where 0 means that the type of plant is not present and 1 indicates that the plant is used for the maximum possible number of hours (for example round-the-clock for a generator set). The model reflects changes in plant composition and consequently in other aspects of mountain hut management when, for example, the generator set is replaced with a photovoltaic system.

Therefore, the energy produced forms the energy stock that is consumed according to the number of service points at the mountain hut, i.e. plants that require use of electrical energy; unused energy is considered to be dissipated. If energy production involves the use of fossil fuels, the production of emissions of CO_2 in the atmosphere is quantified according to the type of fuel used (Contaldi et Ilaqua, 2001).

The model has been suitably adapted in cases where electrical energy is tapped from the mains supply. In this case, insofar as there are no limitations, and the energy is not produced in excess in relation to management-related needs, demand corresponds to energy consumption.

The aggregate model

The aggregate model incorporates part of the components of the model of the individual mountain huts.

The data regarding overnight stays, waste, number of rotations and procurement, distinguishing between rotations by helicopter and those with other means, represent the sum of the flows of the individual mountain huts.

With regard to energy production, the effective use of generating sets to produce electrical energy (determined according to the relative importance of the plant) has been calculated at aggregate level. According to this data, the model has been structured in order to highlight the modifications that occur when a given percentage of this production is replaced with the production of energy using photovoltaic systems.

The stock of emissions into the atmosphere is the result of the sum of the production of CO_2 by fuel and that due to rotations of the helicopter. This pollutant has been considered when assessing emissions as it is that to which reference is generally made when considering contribution to the greenhouse effect. However, where further experimental data is available, the model can be extended to take into account the production of other pollutants.

The value of the following variables is also defined at aggregate level:
Per-capita production of sludges (where the value is deduced from legal parameters regarding the size of the tanks).
Weekly energy consumption of service points.

Maximum hours of functioning of the plants which determines the relative importance of the plants by individual mountain hut.

Determining the total installed power at aggregate level, it is possible to estimate the cost of replacing the potential energy produced by a fuel-powered generator set with, for example, a photovoltaic system.

For this purpose, it is possible to identify a correspondence between the installed meters of photovoltaic panels necessary to produce the amount of energy corresponding to an installed kW of a generator set. Associating a corresponding cost to installation of a square meter of a photovoltaic panel, it is possible to make an initial quantification of the total cost of replacing a given percentage of the plants installed.

Simulation

Determination of the reference time unit of the simulation

With regard to the time unit used in the model, i.e. the dt, the following must be specified. Generally, the lower the dt, the closer the simulation to reality. For the type of system to be described, the optimal time unit would have been the single day. However, considering the particular distribution of overnight stays during the year and in the absence of specific data, it would have been necessary to define daily coefficients in order to estimate the number of daily overnight stays at the mountain hut. This procedure would have increased the discretional nature of the model; for this reason, it has been decided, in an initial phase, to restrict determination to a weekly estimate of overnight stays in order to highlight, first of all, the relationships and to describe the trends of the main characteristic aspects of mountain hut activity. Therefore, all the values of the components of the model refer to the week, the time unit within which the algorithm defined, in this case Euler's algorithm, is computed.

Dynamic simulation by individual mountain hut

In order to permit adaptation of the model to the management system of each mountain hut, it has been considered advisable to allow the potential user considerable freedom in defining the values of the individual variables.

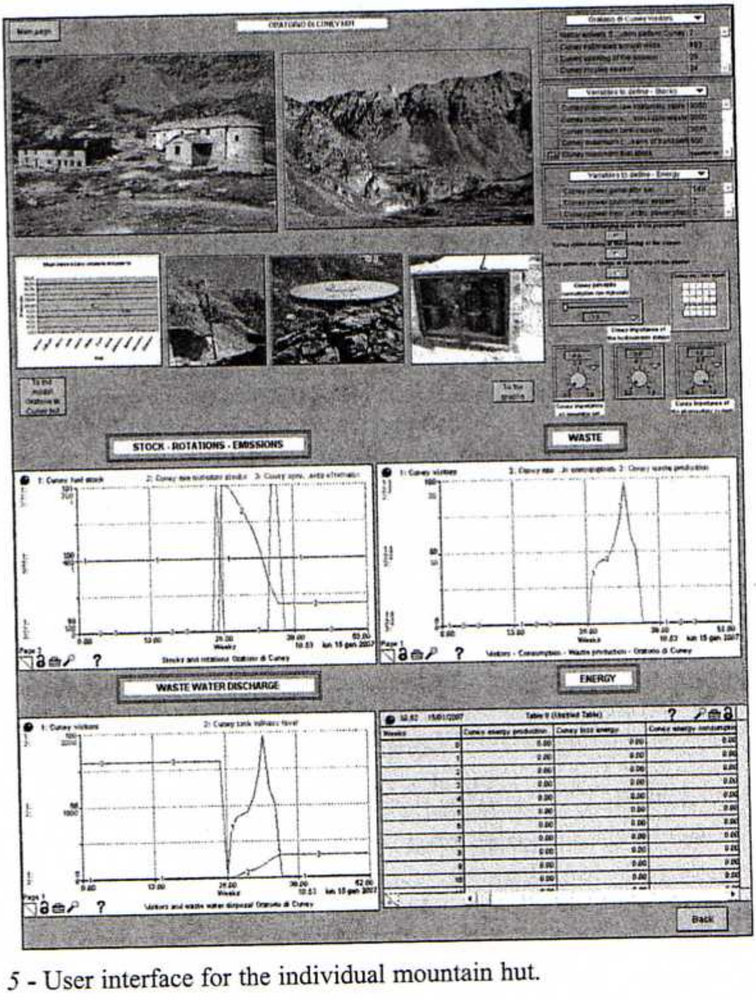

Fig. 5 - User interface for the individual mountain hut.

As can be seen in Figure 5, the interface for the individual mountain hut combines a set of tools provided by STELLA language to modify the simulation settings of the model, including the possibility of inserting the value of a number of variables, as can be seen in Table 2.

TABLE 2

SIMULATION – VALUES DEFINABLE BY THE USER

Item	Description
Visitor arrivals distribution pattern	Insertion of a value from 1 to 4 corresponding to one of the 4 influx models.
Estimated annual visits	Presumed value of expected visits in the year.
Opening of the season	Indication of the week of opening of the mountain hut.
Closing season	Indication of the week of closing of the mountain hut.
Maximum raw materials stock	Maximum quantity of raw materials that can be stocked at the mountain hut.
Maximum fuel stock	Maximum quantity of fuel that can be stocked at the mountain hut.
Maximum tank capacity	Indication of the maximum capacity of the sedimentation tank.
Maximum capacity of the means of transport	Indication of the maximum quantity that can be transported to the mountain hut.
Maximum amount of stockable waste	Indication of the maximum amount of waste to be stocked at the mountain hut.
Power of the generator set	Indication of the power in kW of the fuel-powered generator set.
Power of the hydroelectric power plant	Indication of the power in kW of the hydroelectric power plant
Power of the photovoltaic system	Indication of the power in kW of the photovoltaic system.
Importance of the generator set	Indication of the hours of use of the generator set with coefficients from 0 to 1 (1=24h/24).
Importance of the hydroelectric station	If present, is equal to 1.
Importance of the photovoltaic system	If present, is equal to 1.

Considering the initial settings and using the interface of the individual mountain hut, it is possible to verify various changes in the management profile of the mountain hut due to modifications in certain parameters. A number of examples of possible modifications and their effect on other variables of the model are described below.

Increase in per-capita consumption of raw materials

Adjusting the specific "Slider Input Device", it is possible to forecast how the variables behave as consumption of raw materials increases (which could depend, for example, on extension of the dishes proposed, etc.).

Arrivals being equal, there will be a higher number of rotations of the store and therefore of use of means of transport. This also implies increased production of waste.

Reduction in the relative importance of the generator set

The relative importance of the generating set is the variable that indicates the number of hours for which this is used to produce energy. A reduction in use implies:

a reduced need to stock fuel and therefore a reduced number of rotations for procurement and a consequent reduction in transport-induced emissions;

a reduction in emissions stemming from switching from a non-renewable source to a renewable source of energy production.

Other information that can be obtained refers, for example, to changes in the energy production profile as methods of production vary, with reference to the amount of energy produced and energy dissipated.

It is clear that quantitatively-accurate data can be obtained only through empirical recording of certain values which, in the model, as such, are based on bibliographical research. Knowing for example the power of the service points installed by single mountain hut, it is possible to assess suitable scaling of the plants. Also, establishing the relationship between the reduction in rotations and the effective cost of transport for the manager, it is possible to obtain an initial quantification, functional for a cost-benefit analysis, of a decision such as to replace use of the generating set with another method of energy production.

Simulation options for the aggregate model

The interface of the aggregate model permits access to the interfaces of the individual mountain huts included in the model and provides a set of tools to modify certain predefined options. A number of simulation options are described below.

Replacement of fuel-powered generating sets

An option makes it possible to verify the change in the aggregate environmental profile of the mountain huts of the Aosta Valley. The model is set to define the percentage of generating sets replaced with photovoltaic systems. This means that the model can be extended in order to quantify the investment required: knowing the installed power of the generating sets, it is possible to calculate the equivalent surface of photovoltaic panels necessary, taking into account conditions of sunlight of the sites where the mountain huts are located and, consequently, to make an economic type assessment.

As seen at single mountain hut level, the effects on procurement of fuels and therefore on rotations, which will be reduced, together with emissions into the atmosphere, will be verified.

Reduction of weekly consumption of service points

This data is used to establish the relationship between energy consumption and the presence at the mountain hut of a more or less high number of service points. At single mountain hut level, it has been assumed that this data is one of the main decisive factors in determining energy consumption, related partly to the number of persons at the mountain hut, but not directly proportional to this insofar as certain household appliances, for example, are used regardless of the number of visitors (for example the refrigerator).

Intervening on this variable in the simulation could correspond to simulating the Public Administration's decision to provide incentives for the purchase of household goods belonging to higher energy efficiency classes.

Therefore, the deviation between potential energy that can be produced at the mountain huts considering existing systems and the energy required would be highlighted and, therefore, the possibility of reducing use of an existing system or of re-scaling the systems if economically convenient.

Reduction of the waste production rate

A reduction in the production of waste may, for example, reflect a decision to give priority to a policy of purchasing goods with reduced packaging (for example with incentives for introducing Environmental Management Systems). This aspect does not refer directly to the production of emissions by the mountain huts but contributes to mitigating an impact that is, usually, difficult to manage for mountain huts due to their particular location.

Conclusions

The aim of the model is to highlight the relationships between the various components of managing a mountain hut and between these and the external environment. The approach taken when constructing the model was directed towards providing sector business operators and the public administration with an instrument able to provide effective support. It can certainly be extended and integrated with quantitative data to be collected, necessarily, at the mountain huts. In particular, to make a cost-benefit analysis, it is important to detail the component tied to procurement costs and the cost tied to installation and maintenance of plants for the use of renewable sources.

In particular, with regard to photovoltaic solutions, valuation of the cost attributable to the system must be examined in more detail. If on the one hand, according to bibliography, the cost of a turnkey photovoltaic system is around 5000-7000 €/kW_p (ENEA, 2006), the higher cost for installation of the plant at a high altitude must be considered. Also, further costs, such as those tied to maintenance, replacement of the Inverter and dismantling of the plant can also be assessed (Giacomelli et al., 2003).

Furthermore, the model could be enlarged to extend the analysis to the hypothesis of introducing further electrical energy production plants.

In any case, it is useful in this initial phase to highlight the correlations existing between the processes, also to improve awareness of mountain hut managers and of the public administration about problem of environmental management, considering all the related aspects.

Acknowledgments

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