CHECK-Sim: Cultural HEritage ChecK-up Simulation model

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ABSTRACT

In Italy there are almost 20,000 cultural towns, 40,000 castles and gardens, 3,000 museums, 10,000 churches, 200 archaeological sites and a considerable number of old libraries and archives. Italy owns the largest number of world heritage (49 out of the 981 UNESCO list).

These cultural resources represent an essential factor for the Italian tourism industry and in general for the national economic system.

Italy needs to distribute over the year its tourist offer. Except for the art cities like Rome, Florence or Venice, the Italian tourism today is mainly concentrated on the so called “beach tourism” (seaside travelling in summer time). Therefore it is more and more necessary to promote cultural heritage as an essential source to attract tourists throughout the whole year rather than to focus only for the seaside beauty.

Being aware of the economic importance and the complexity level of the cultural tourism process, recently there have been a lot of research initiatives focused on the different aspects of the problem.

The paper aims to describe a research work, in progress, where the objective is to study the risk analysis and the decay process of the “movable” (transportable) artwork (objet d’art) due to different reasons: aging & preservation location; natural & criminal events; inappropriate restoration and finally transportation & exhibition time.

Monitoring the state of an artwork is a complex process. The presence of many endogenous and exogenous variables which interact each other through different feedback loops creates non-linearity.

The restoration process analysis represents the main subsystem of a System Dynamics (SD) model which has been developed and includes the characteristics of the artwork type under examination with relative fixing time period together with the workforce (restoring team) years' experience. Different risk elements (pollution, vandalism, natural events …) are taken into account and a cost-benefit analysis is also elaborated.

A first version of a microworld SD simulation model has been developed and some interesting results will be presented. The prototype model presently is configured on the paper sculpture artwork (paper mache).

Keywords: Cultural Heritage Artwork, Risk Analysis, System Dynamics Modeling

1. Background Reference

1.1. Cultural Heritage – A general present domain analysis

For any country, cultural heritage represents a precious and important resource, not only from historical and social point of view but also in economic terms. In fact it acts as an essential point for the tourist attraction. This is particularly true for Italy, which owns the considerable part of the world's artistic heritage [7].

According to the data provided by the MIBACT (Italian Department of Heritage, Cultural Activities and Tourism), in Italy there are almost 20,000 cultural towns, 40,000 castles and gardens, 3,000 museums, 10,000 churches, 200 archaeological sites and an important number of libraries and archives [5]. In the 981 UNESCO world heritage sites, 49 are in Italy, the nation with the largest number of sites [3].

Presently, Italy owns approximately 5,500 structures such as museums and archaeological sites (only U.S. can praise by its 8,100), and holds the record for national parks in Europe (23, compared to 14 in Spain and 9 in France) [10]. These cultural resources represent an essential factor for the Italian tourism industry.

Italy needs to distribute over the year its tourist offer. Except for the art cities like Rome, Florence or Venice, the Italian tourism today is specifically concentrated on the so called “beach tourism”; [8] therefore it is more and more necessary to promote cultural heritage as an essential source to attract tourists throughout the whole year.

: Cultural heritage tourism's definition of National Trust for Historic Preservation is "travelling to experience the places and activities that authentically represent the stories and people of the past and present. It includes historic, cultural and natural resources" [1]. This is a generic definition, because it is not so easy to define and separate cultural tourism from other forms of it, but it is certainly important for the national tourism, especially for Italy, that owns so much of the world's cultural heritage.

The tourism trend analysis reveals that guests spend more in the art cities than in all other places. Since 2009 most of the tourists who arrive in Italy have cultural reasons. In addition, these tourists stay for a longer time than the non-cultural tourists (this is not true only for beach tourism) [11].

In Italy, the tourism in the art cities has grown from 2000 to 2010 by 2.6% per year for arrivals (8 million more people). It has been the same for museums: from 2000 to 2010, the number of visitors has remained unchanged in the South, while in the rest of the country has risen by 2.8% per year [11].

In order to improve tourism in general it is absolutely necessary to invest in infrastructures, services and guest accommodations, but this is not enough and the above numbers show how the cultural tourism is growing, but also the fact that, especially in the south of Italy, the seaside tourist destination still remains the chief. All these reasons brings to the consideration that Italy should focus more and more on the enlargement of the cultural tourism.

1.2. Cultural Heritage - Scenarios and future perspectives

It has been already underlined that it is not so easy to separate cultural heritage from other forms of tourism, but it's important to reflect on its development. It is necessary to identify the key elements that describe the cultural heritage status and trends. The cultural heritage of a region is not only one of the major sources of socio-economic development for local communities, but also a valuable growth driver for attractiveness. It produces a considerable supply increase that more and more attracts “qualified tourists” which consequently meet their complex and articulated needs as entertainment, cultural studies, aesthetic pleasure and popular cultural traditions.

According to the guidelines defined by MIBACT, in consultation with the local (archaeological, historical, artistic, architectural, environmental and underwater artworks) consists of the following phases: historical / technical study, diagnosis, intervention, conservative monitoring, “musealization”[1] and fruition-exploitation [10].

In each of these stages of the process we have several projects on the study and the technical and humanistic testing of new technologies, more or less integrated with each other.

The industry is full of spot interventions, heavily monitored by the superintendents, but often disconnected from each other, so as to dissipate the information that these projects generate. Data and information remain in the know-how of the experts.

There are currently in Italy many national and local projects aimed to improving the exploitation and the musealization of the cultural heritage. However, considering also the limited public

[1] Preparation to be placed in a museum

budget, it is useful to improve the efficiency of the management of economic resources and the effectiveness of the processes of preservation of cultural heritage.

Cultural tourism is a complex system that can help to improve the economy in our country therefore any innovation initiative in this sector welcomes in order to gain possible benefits due to increasing trades, infrastructures and manufacturing.

Considering the present world crisis and in particular the Italian economic crisis, the technological and organizational innovations are easily overlooked and are not considered as a source of recovery and development. However, we believe that persisting in the wrong use of the limited resources available is not the winning path. Innovation should focus on design and implementation of management tools to understand where it is better to use the limited resources available. Only in this way we can have important benefits in the medium- long term.

These investments could produce returns in efficiency and effectiveness.

We should "optimize" the cultural heritage conservation and the management system in order to avoid a possible heritage impoverishment. Therefore it is necessary to equip the public administration and authorities (for those purposes) by management tools in order to encourage the cultural heritage exploitation and hence increase the potential tourism offered by the attractiveness of the area.

Being aware of the complexity level of the problem, it rose the need of a methodology supported by some operative instruments in order to analyze the process and develop a tool to evaluate alternative scenarios and support decision makers.

1.3. Cultural Heritage - Process analysis and decision tools

In Italy presently there are many projects in progress focused on cultural tourism process, analyzing different phases of the overall management.

In particular, regarding the conservation phase, there are different historical cases studying the cultural heritage decay/lost due to natural (such as earthquakes, floods, …) or human (such as vandalism, terrorism, …) events. For example the collapse of a very important Pompei wall from 2010 up to date. This catastrophic event, generated disbelief but also a great interest for new methodologies and tools to evaluate in advance the possible risks for any kind of cultural heritage.

The domain analysis led our research working group to interact with other projects which use to cover, more or less, the common objectives. We discovered that almost the total number of these

projects were mainly focused on the identification of risk factors characteristics rather than to understand and possibly manage the overall risk process dynamics.

Among the projects with an integrated view of risk factor analysis, it can be mentioned for example, the European project "EU CHIC - European cultural heritage identity card" [14] and the Italian "SIT - Carta del Rischio" project [15]. However, both projects are focused on the cataloguing of the Cultural Heritage and their risk maps, rather than evaluating what-if simulation analysis.

We believe that the Cultural Heritage risk analysis should include different aspects of the artworks decay process beside their “soft” and “hard” interactions. Hence, it is essential to look at the problem with a Systemic approach.

In addition the Check-Sim project future developments aim to integrate data through specific methodologies or tools (such as techniques of Geomatics [16], a vulnerability matrix (VM) [13]), and/or in general the project results implemented by other partners projects as SMooSH (Smart Monitoring of Historic Structures) [17], IT@CHA[2] (Italian Technologies for Advanced application in Cultural Heritage Assets) [10], etc.

2. Project Objectives

In accordance to the above considerations, the objective of the Check-Sim project was focused on building a tool in order to better support decision makers in the management of cultural heritage through what-if simulation analysis.

"Cultural heritage" includes various types of item: a cultural archaeological site, a park, but also a musical instrument or a paper design. So it is easy to understand that the risk factors have different nature and magnitude for each item type. Despite of the possibility to unifying the different types of risk factors for cultural heritage in a single map, a detailed analysis of the depletion of the cultural heritage, of its risk factors, and the interaction between them, show that it is impossible to identify the acceptable standards for all forms of cultural property. So it is impossible to define the uniquely good practices.

Consequently, the overall project started foremost by classifying the movable (transportable) Italian artwork by their potential decay characteristics. Once this general classification was

[2] IT@CHA is a large research project supported by Italian National Operational Programme (PON) "Research and Competitiveness" 2007-2013. The project is implemented by the partnerships including enterprises, research institutions (such as CETMA, the project leader) and Italian universities. The CHECK-Sim model idea was born in a workpackage activity of IT@CHA project, coordinated by TERIN Consortium.

defined it has been selected the so called “organic” based (i.e. wood, textile, leather, rubber, paper, …) artworks excluding (by now) the “inorganic” based (i.e. metal, glass, alloy, …) ones.

Among the movable organic artworks we have selected the paper made sculptures; specifically paper machè (in Italian “cartapesta”) artworks.

Once the focus has been concentrated on the “cartapesta” sculptures the risk factors for general decay of the artwork were investigated. These factors were classified as following:

- External events:
    a. Safety risks
        i. Natural (hydrological, earthquake, …)
        ii. Technological (industrial, transportation, fire, …)
    b. Security risks
        i. Human (theft/robbery; vandalism; …)
- Internal elements:
    a. Quality of the original paper and glue used
    b. Conservation environment
        i. Temperature
        ii. Relative humidity
        iii. Light and ultraviolet radiation
    c. Inappropriate restoration
    d. Fruition/exploitation;

In a way the "External events" express the concept of ***hazard***, while "Internal Events" represent the ***vulnerability***. This correlation with the concepts, is commonly used in the risk analysis literature [19]. While the last factor "Fruition/exploitation" represents the use in religious events, non-permanent exhibitions, etc and it can be enabled or disabled in the specific case.

Through a systemic approach the dynamics of the artwork (paper machè/cartapesta) decay were investigated and a system dynamics model has been developed.

The project main objectives are:

- to monitor the artwork decay state once the origin state, i.e. the eventual passed restorations and the present conservation environment are defined;
- to simulate alternative scenarios in order to best control and manage the artwork “health” state;

- to evaluate cost and benefits (social & economic) of possible artwork fruition/exploitation.

2.1. The model structure definition

The model has been developed through different subsystems, each one interacting with others due to a complex systemic approach.

The model structure definition includes:

– Restoration subsystem; analyzes how the artwork state evolves in respect of a desired level and in presence of limited resources.
– Decay subsystem; represents the artwork state influenced by external risk factors dynamics.
– Preservation subsystem; details mainly the environmental feedback loops due to artwork conservation conditions.
– Cost & Revenue subsystems; appraise the economic & social costs and benefits.

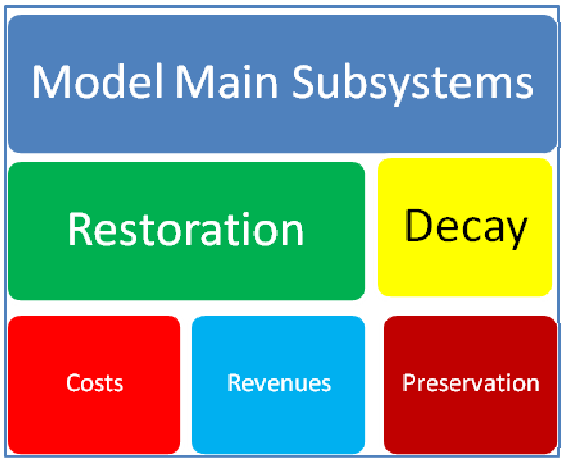

Figure 1: Model main subsystems

A simplified overall structure of the model is depicted in Figure 2: Simplified overall model structure.

The conservation environment definition and artwork restoration process were analyzed through a continuous interaction with a paper sculpture restorer expert. The knowledge acquisition process encountered some difficulties due to the “technical” language incomprehension (from both sides!).

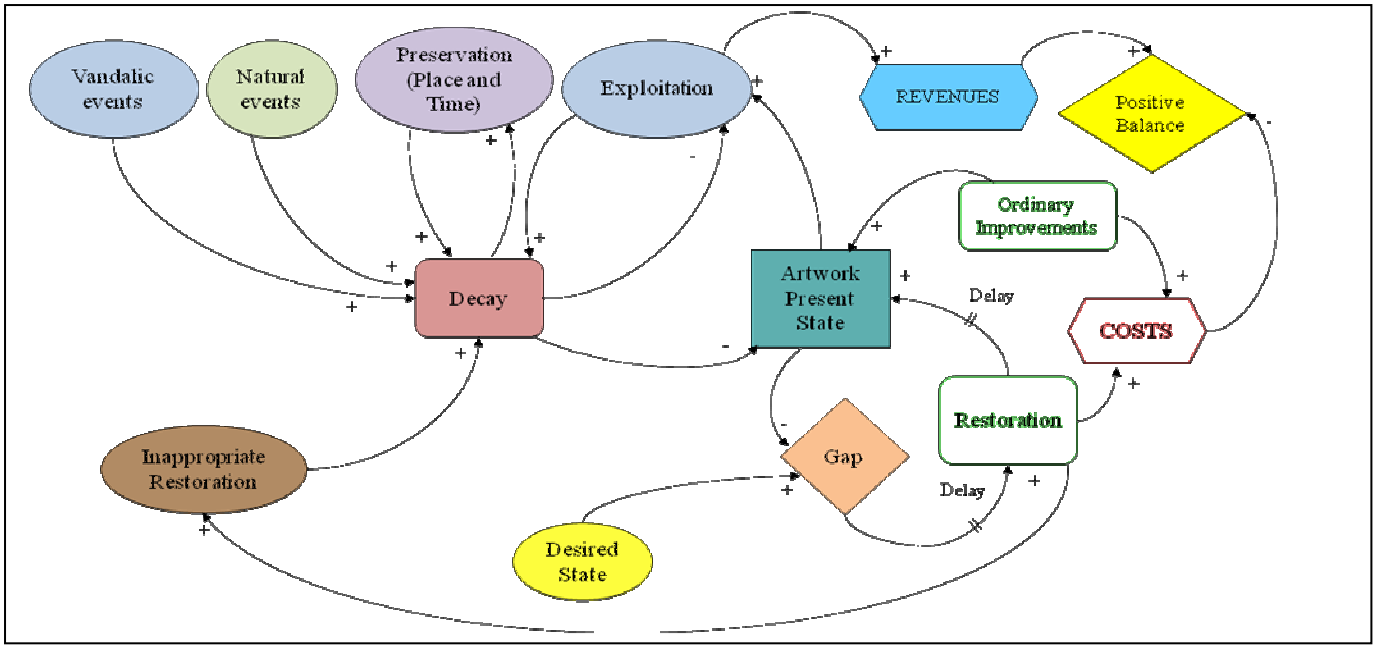

Figure 2: Simplified overall model structure

Once the knowledge acquisition for the main subsystems was completed, in order to analyze and elaborate the overall knowledge acquired, together with process experts and potential users, some work group meeting sessions were organized. These meetings integrated (and in some situations modified) the model subsystems interrelation hypothesis.

The work group meetings were also very useful to better identify both the simulation time period horizon and the main model decision levers.

2.2. The main endogenous & exogenous variables

The model has been developed around the principal variable which represents the state of the specific artwork (paper machè/cartapesta) which we would like to monitor during the simulation time. A number of causal-loop diagrams were sketched in order to better understand the dynamics related to the artwork state through the influence of various endogenous and exogenous variables.

While the restoration process (both the ordinary and the extraordinary one) normally contributes to increasing (at least at the first instance) the artwork state after a delay time (dependent on the restoration complexity and initial artwork state), the time variable (aging) together with artwork conservation location (Biological Risks) usually influence negatively in a non-linear way. The main environmental variables in our case (cartapesta) are represented by the temperature,

humidity and light exposure level of the conservation place (Real climatic conditions) in respect of an optimal value (Ideal conditions).

The optimal climatic range of the conservation place is deductible by the standards and regulations (such as UNI 10586 [20]), where these do not consider the paper machè, it is likely to look at the paper in general. The “Ideal conditions” include not only a range of ideal climatic conditions, but also the context conditions that influence some variables of biological risk, as pollution (considered as exogenous pollution, but also as due to causes typically relating to climatic conditions). Obviously the optimal values (Ideal conditions) are themselves influenced by efficient (and usually expensive) instruments which are not always present in the artwork conservation place.

The climatic conditions considerably influence the artwork state, when the non-optimal values persist for a long time, creating an ideal environment for mildew and pests development.

The "Real climatic conditions" are calculated including the above variables together with other environmental variables relationships.

Overall, the climatic conditions are obtained as a function of the following variables:

$$Real\ Climatic\ Conditions = f(temperature; Relative\ Humidity; light\ exposure)$$

For each above variable the value of its intensity is evaluated and then analytically its incidence on the “Real climatic conditions” variable is calculated.

For example the incidence of “Relative Humidity-RH”, one of the endogenous variables considered, depends on the exogenous "External RH" variable which express the outdoor Relative Humidity value. The "incidence of Relative Humidity" is calculated by the following equation, where RH represents the "External Relative Humidity":

$$\begin{cases} if\ RH < 30\ o > 60: f(RH) = 3{,}3 * 10^{-6} * RH^3 - 5{,}2 * 10^{-4} * RH^2 + 2{,}8 * 10^{-2} * RH - 6{,}4 * 10^{-3} \\ else: f(RH) = 0 \end{cases}$$

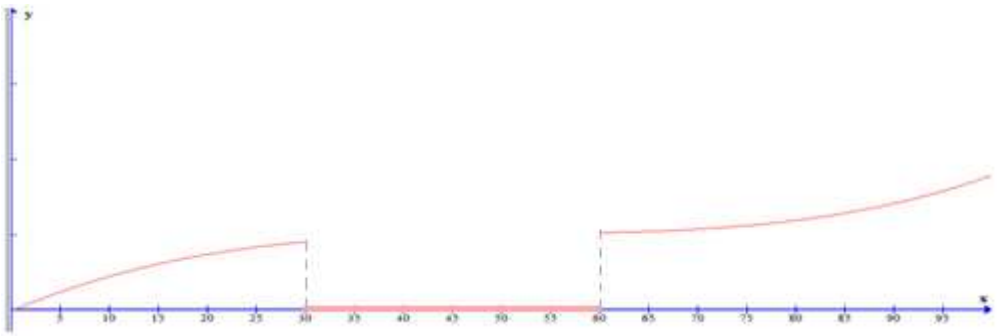

Figure 3: Incidence of Relative Humidity diagram

There are two important variables which heavily influence the artwork decay due to the environmental conditions and these are the location pollution state where the artwork is preserved and also the microbiology variables including different pests attacks.

On the other hand, the biological risk can be limited through actions in defence of the status of the artwork (Incremental improvement).

There are two different types of improvements:

- Dusting & precise improvements; direct actions on the artwork,
- Preservation environmental improvements; indirect actions changing artwork placement conditions (temperature, dehumidification, etc.).

A simplified influence diagram (

Figure 4: Artwork conservation location & environmental influence diagram) depicts the above description.

Another group of variables which could definitively influence the artwork state decay is represented by what was defined, in the opening paragraph of this chapter, as external events. Even though these variables mainly could be considered as exogenous variables they are partially calculated also by endogenous variables together with statistical data elaborated during each simulation run.

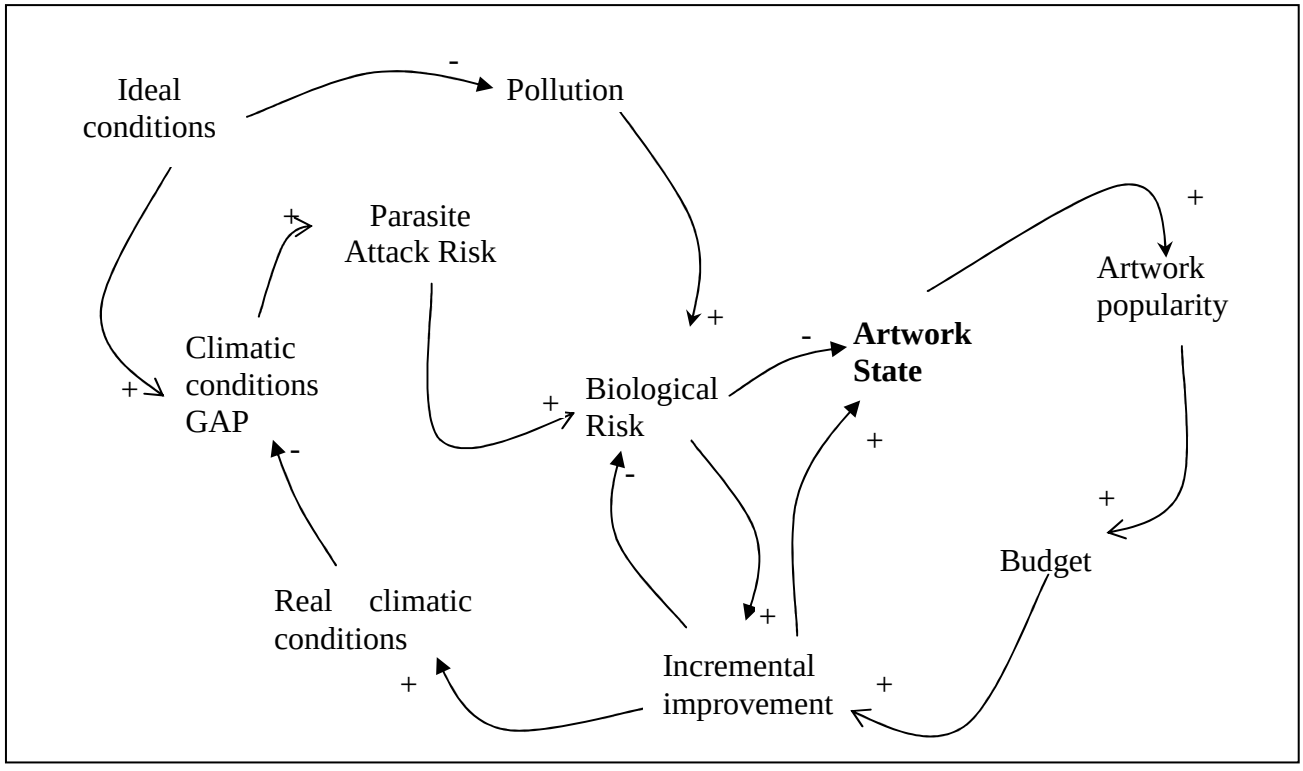

Figure 4: Artwork conservation location & environmental influence diagram

Again a simplified Causal Loop Diagram(CLD) regarding external event variable and in particular Security risks dynamics is showed in Figure 5 : Security risks influence diagram.

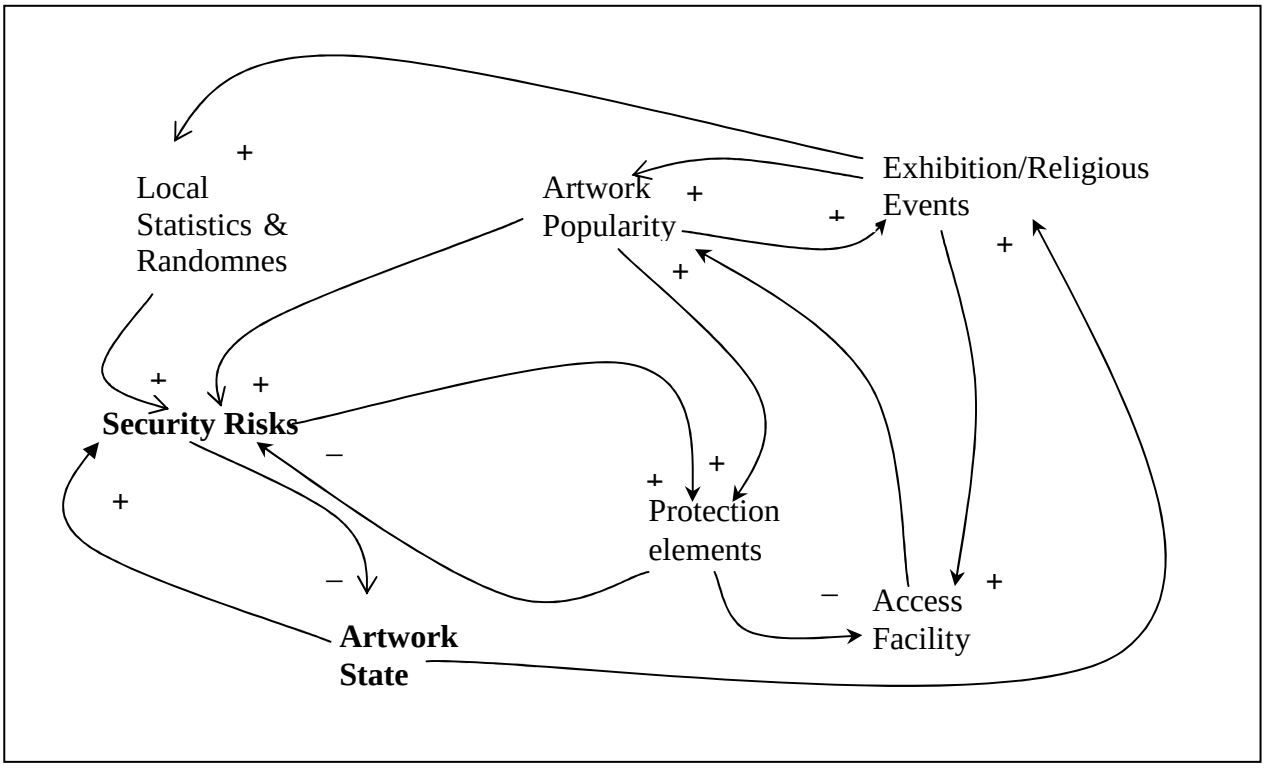

Figure 5 : Security risks influence diagram

Regarding the time variables of the model, the following terms have been defined:

- The time horizon of the overall analysis will include a period of five years.
- The time step of the simulation is fixed to be a month.
- The time interval by which the simulation can be paused in order to make changes to the policy decision will be six months.

3. Policy levers and simulation

The potential users of the Check-Sim model are identified in local government cultural heritage administrators; government department responsible for the artwork treasures, museum managers and any other decision maker with territorial or national treasure (artwork) safeguard responsibility. The model can be helpful to support different action evaluation “driving” the policy levers of specific user responsibility.

The ideal model end-user should be involved (at least) in the validation phase in order to be aware of the model general structure and having identified the policy levers through which he/she needs to simulate different what-if analysis.

3.1. What-If Analysis and the model interface

Up to date the model, for the artwork common subsystems (restoration process, general decay process and cost & revenue), has been developed in a quite general way. While the preservation subsystem and artwork specific decay process, as already mentioned, is configurated for monitoring paper machè (cartapesta) risks.

The model interface (control panel) for the present artwork (cartapesta) is shown in Figure 6: Check-Sim model control panel.

The policy levers:

- desired artwork state,
- average restoration time,
- number of restorations,
- pollution level of preservation location,
- artwork protection level,
- …

are all defined by sliding bars at the left side of the control panel.

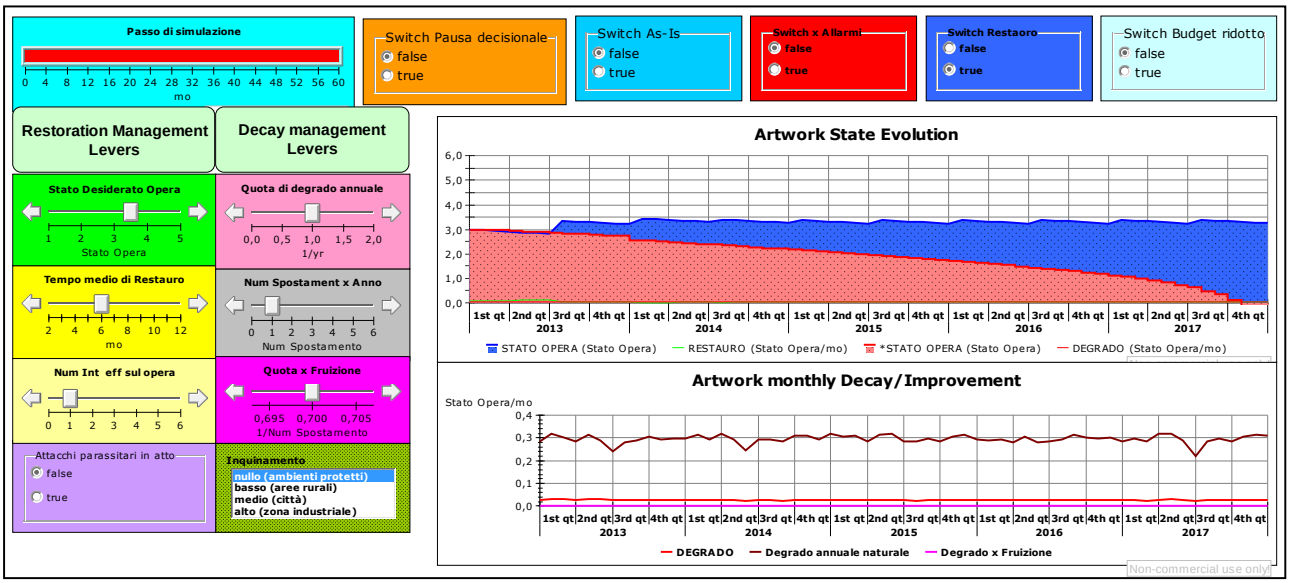

Figure 6: Check-Sim model control panel

The alarm, decision time, reduction budget and other switches can be set by radio buttons and are identified on the top of the panel.

The two main outputs representing the artwork state (stock) and decay/restoration (flows) through the simulation time are depicted by the central graphs.

The model is developed in the Powersim© Studio 9 environment.

3.2. The first simulation results

The model is presently in the validation phase, but some first simulation tests are already executed.

Conceptually these tests are oriented to evaluate three type of scenarios:

1. **AS-IS Simulation**; how the state of the artwork will evolve if no decision action takes place.

   In order to run this (and all the other scenarios) simulation it is necessary to identify the artwork origin:

   - Where (the artwork provenience location);
   - When (the artwork age);
   - What (possibly the "material" with which artwork was built);
   - Who (possibly the artist name, to deduce the quality of raw materials and a possible inappropriate restoration or remakes from other artist);
   - History (possibly where and how it was conserved/restored);

   The results of a simulation with AS-IS scenarios is shown in Figure 7: An AS-IS simulation result.

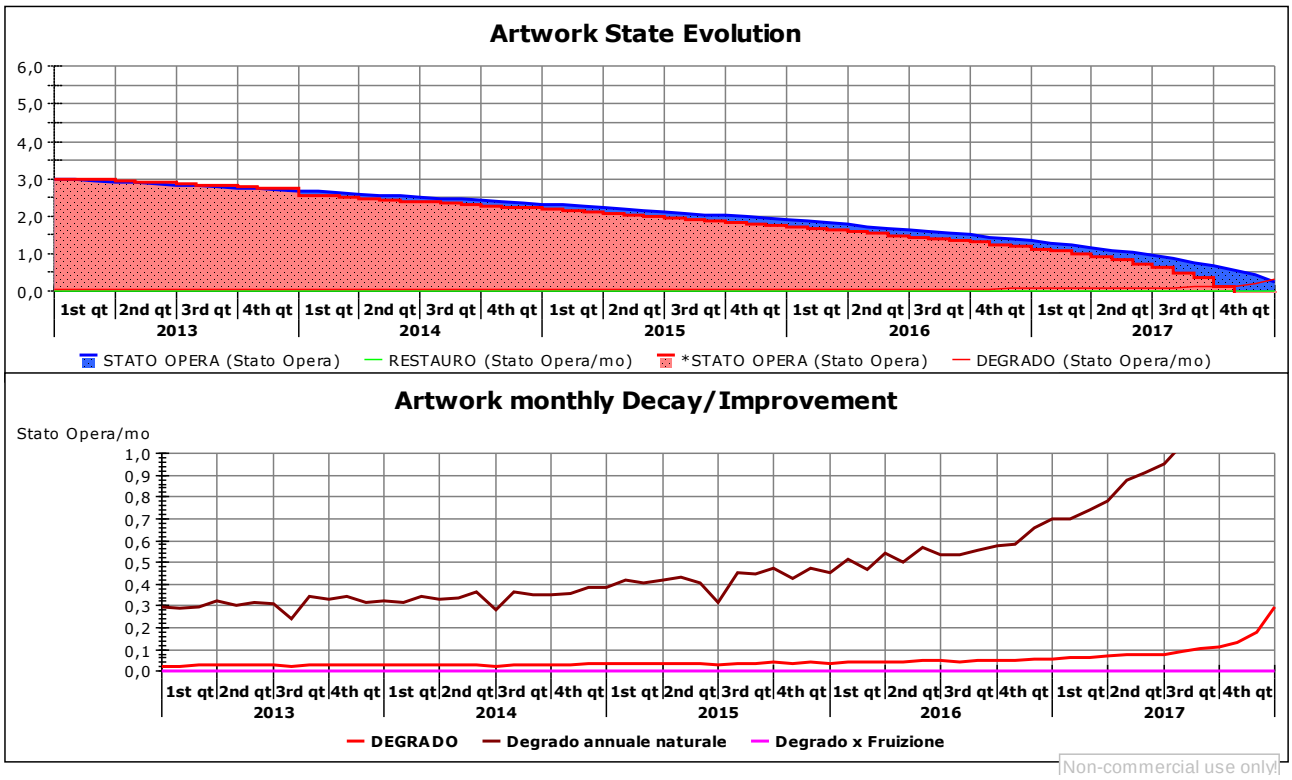

Figure 7: An AS-IS simulation result

2. **WHAT-IF Simulations**; a number of simulations to monitor different scenarios in relation of different policies.

The Figure 8 : A WHAT_IF simulation result depicts the model output results related to the policy of planning to make use of an artwork (cartapesta) for every Christmas period of the year (1 full month) through the simulation period term (5 years).

3. **IF-NOT Simulation**; monitor what would be the possible artwork state risk level if specific interventions were not planned in time and in advance.

   For example, when the paper maché(cartapesta) is planned to be exhibited in some religion events, during which it needs to be at least in an “acceptable” state level. If such a condition is not true the model sets an alarm.

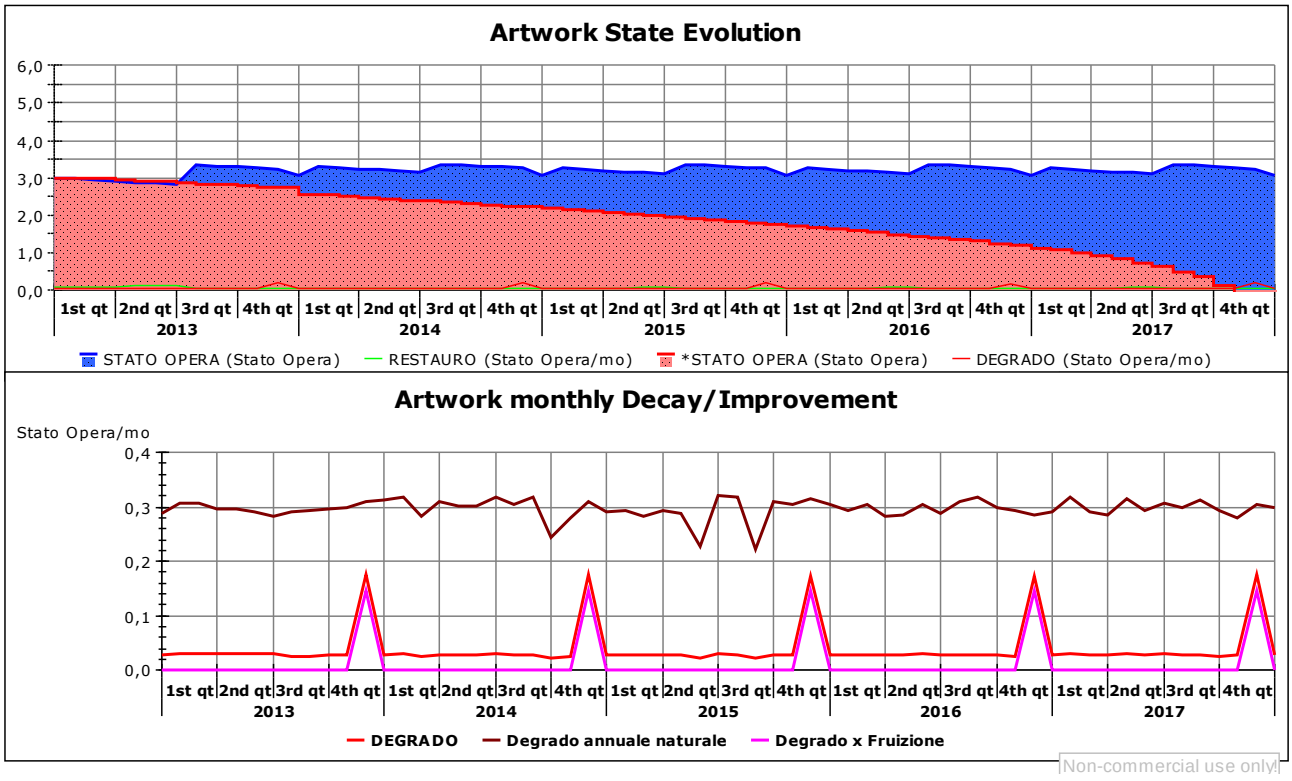

Figure 8 : A WHAT_IF simulation result

4. Conclusions

The tourism industry is a very complex system and its overall process development and sector impact analysis needs the involvement of a huge number of components and hence an enormous effort.

The project, where the Check-Sim SD model is one of its implemented results, primarily aims to put in evidence the high potentiality of the cultural heritage tourism domain strengths in the Italian economic growth. So the specific target has been pointed to identify the cultural heritage tourism, as a possible solution by attracting tourists distributed throughout the whole year.

Considering the present world crisis and in particular the Italian economic situation, we believe that persisting in the wrong use of the limited resources available is not the winning path. Innovation should focus on design and implementation of management tools to understand where it is better to use the limited resources available. Only in this way we can have important benefits in the medium- long term.

In our opinion Check Sim Model could be a good starting point to support government administration and territorial authorities for cultural heritage management, by making some

advanced risk analysis and hence by promoting the controlled cultural tourism and enhancing the attractiveness of the country.

The objective of the project started by adopting a systemic approach to analyse the overall complexity of the cultural heritage management and so to realize an experimental operative instrument in order to facilitate alternative decision evaluations for the final users (identifiable in public administration, museum directors, superintendents or anyone who has the task of assessing the actions for the protection of the artistic heritage) through a dynamic simulation tool.

The study of the domain allowed us to understand that cultural heritage includes different kinds of issues. Where the variables for the risk definition are similar, the magnitude and the correlation between these present great differences. So the model experimentation was oriented towards a specific context in the domain of transportable artwork category i.e. paper-mâché (cartapesta).

The model has been developed through different subsystems (Restoration; Decay; Preservation subsystem and Cost & Revenue) and allows to evaluate the evolution of Artwork state:

- without specific interventions (what happens if we do not make improvement actions) - AS-IS simulations;
- to make a series of simulations by creating alternative scenarios (WHAT IF and IF NOT SIMULATIONS).

The model aims to monitor the artwork (paper-maché) “health”, starting from its current state and simulates how it evolves in presence of natural events, possible vandalism acts and possible fruition plan, always keeping in mind the natural deterioration of the artwork and so suggests the necessary and /or desirable restoration. It helps to understand why and how much the artwork state will deteriorate by aging and evaluates possible actions needed to better protect and preserve it (frequent and fast incremental improvements or long and high quality restoration).

The model provides useful suggestions related to the possible risks to which the artwork is subjected to and also on the costs and the revenues expected in the medium term. It also suggests the best fruition plan compatible to the “acceptable” risk level.

The significant advantage of the model is to help the end-users to better evaluate the risks to which an artwork is submitted. The adaption of such tools can save considerable costs (not only economic) to repair the possible consequences of ignored or underestimated risks.

In addition the estimated costs & revenues of alternative planned actions are also another powerful feature of the model and can support decision makers to achieve long-term "spending plans" in order to obtain the necessary budget for the restoration and enhancement of the cultural heritage.

Finally the Check-Sim project future developments are planned to:

- validate the model with real historical data and make a final revision based on the results of the validation;
- integrate data from specific methodologies or tools (such as techniques of Geomatics [16], a vulnerability matrix (VM) [13]), and/or in general the project results implemented by other partners projects as SMooSH (Smart Monitoring of Historic Structures) [17], IT@CHA (Italian Technologies for Advanced application in Cultural Heritage Assets) [10], etc.
- extend the model with other forms of Cultural Heritage: ahead of other type of movable artworks, then also to architectural works.

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