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Modelling framework for sustainable co-management of multi-purpose exhibition systems: the “Fiera del Levante” case

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Abstract

An exhibition system is typically a physical open space made of several buildings devoted to performing demonstrations or social activities. Several examples of exhibition systems can be found world wide. The management of these spaces, even in presence of a limited number of activities, requires significant efforts: safety, welcome, merchandising, public services, etc. Nowadays, the new trend is to offer multiple, contemporary use of exhibition spaces, allowing exhibition events and regular social activities (commercial, cultural, etc.) to be dynamically intertwined, either to endeavor the huge economic investments behind infrastructures or to increase the attractiveness of the exhibition activities.

This is the case of “*Fiera del Levante*”, one of the oldest exhibitions located in a fascinating central area on the seaside of the city of Bari - Italy. Here, multiple social scopes, such as multi-exhibitions and contemporary social activities related to public offices, restaurants and entertainment, live together. This is an almost unique setting, which makes Fiera del Levante (FdL) a complex system and makes the management of the exhibition a challenging co-management task.

The paper deals with the development and demonstration of a complex-system modeling framework for the decision support of the co-management of *Fiera del Levante* exhibition system, taking into account the interaction both physical aspects (building assets, infrastructure, equipment, fittings, ...) and intangible aspects (permanent and temporary events, management and business activities, etc) and, of course, considering as a main input the needs of the different stakeholders involved.

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1. Introduction

The research work here presented stems from the collaboration between *Politecnico di Bari* and “*Ente Fiera del Levante di Bari*”, which is the owner of the Exhibition system object of study. An important organizational transformation, characterized by growing complexity, flexibility, contemporary presence of several stakeholders and users during events, is being implemented. Due to this ambitious and innovative project (both in the methodological approach and in the implemented technological solutions) the design and implementation of a smart co-management modelling framework was felt as necessary. A wide range of multi-disciplinary competences were necessary to design, implement and validate a dynamic and multi-dimensional platform for the management decision-support of this complex system, suitable for the new challenging targets of the FdL Exhibition, responding to the following aims:

- Defining a methodological approach for the assessment and implementation of an integrated model, able to properly represent the physical structure of the exhibition system as well as the complex interactions among the many organizational components, to simulate the possible use scenarios.
- Designing and implementing a dynamic decision support system able to manage data (gathered both by traditional methods and by smart systems based on net of sensors and building automation systems), to monitor and control in real time physical components and processes.
- Elaborate scenarios for the different possibility of use of the district and intersection/interference of processes and events, while demonstrating the proposed approach on the field during exhibitions.

In the paper, after a brief description of the case study, the general outline of the co-management framework is presented. More details are provided for the part of the platform devoted to the assessment and management of the building components, with specific regard to the definition of the knowledge framework and implementation of integrated assessment procedures at different scale of analysis implemented in a BIM framework.

1.1. Exhibition Districts as complex systems

In recent times, exhibition systems are being used for multiple contemporary scopes, to foster exhibition events and regular social activities (commercial, cultural, etc.) to be dynamically intertwined. The rationale behind this belongs to a sustainability reason: to endeavor the huge investments behind infrastructures (economic and environmental) and to improve the positive experience of users of exhibition activities (social). The growing need of specialized events, on the other hand, has determined a reorganization of the exhibition sector, fostering the development of managerial structures highly qualified and competitive. A growing number of contemporary stakeholders, with different needs, may turn the exhibitions a complex system to manage, that requires high functional efficiency in checking safety, performing inspections, monitoring in real-time, identifying possible functional conflicts, and so on. In a word, this is a co-management problem, requiring decision flexibility and swift decisions, while endeavoring the great mass of information and data available: an arduous task for the human decision maker in the absence of adequate interpretation models or tools. A deep understanding of the system is thence required, by modeling and systematically orienting the decision making process to the most sustainable solution.

On this basis, the objective of the research work presented is to propose a co-management modeling framework and to design, test and validate an implementation platform for the decision-support addressing a wide range of aims:

- Addressing problems of existing built asset (knowledge, modeling and analysis, assessment, intervention).
- Solving intersection and possible overlap of permanent activities, temporary use, events, with regard to the capacity and modulation of physical spaces, flows and related services (security, fire, parking), rationalization of energy needs to assure sustainability of exhibitions.
- Programming activities and relative resource allocation of regular and extraordinary maintenance and support

- services.
- Analyzing by simulation the occurrence of exceptional events from safety, logistic and sustainability points of view.

1.2. Sustainability

Sustainability, as a concept, is permeating most spheres of our common life, not solely because of a political requirement, but also because it clearly resonates something deep within people's life, even though still they have a poor and undefined understanding of what it means. The World Commission and Development [1,2] introduced the definition of sustainability several years ago, but since then there is still no single agreed and tangible definition of it. There are, in fact, definitions of ecological sustainability, economic sustainability, strong sustainability as well as weak sustainability [3], according to the particular applications, goals, priorities and vested interests. Quite often, the use of this term has no explicit recognition or even evidence of the exact meaning being implied.

Most of the sustainability definitions originate from the relationship between humans and the resources they use. All authors talk about maintenance, sustenance, continuity of a certain resource, system, condition, relationship: in all cases there is the goal of keeping something at a certain level of resource use, of avoiding unavailability for future use. This is also how the WCED [2] defines sustainability: a state or process that can be maintained indefinitely, to keep in existence, to maintain or prolong, to use resources in a manner that satisfies current needs while allowing them to persist in the long term. Similarly, sustainable development has been defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs, or basically as development under the sustainability constraints. Sustainability is presently seen as a delicate balance between the economic, environmental and social health of a community, nation and of course the Earth. The concept of sustainability, however, can be something more than just these three dimensions (namely: economy, society and the environment). These elements in fact, represent the external manifestations of sustainability because the internal, fundamental, and existential dimension isn't considered. The relationship between human features and sustainability in organisations has indeed rarely been addressed so far. It involves important aspects of human being and reflects into the managerial tacit skills, such as capability of innovation, cultural diversity and richness, the respect of oneself and thus of the external living environment. Sustainability, in fact, can be something more grand, noble and dynamic, which involves different fields [4, 5]. The challenge of sustainability is neither wholly technical nor rational. It is one of change in attitude and behavior. Viederman [2] defines the sustainability as a vision of the future that provides us with a road map and helps us focus our attention on a set of values and ethical and moral principles by which to guide our actions. These aspects have been never faced when dealing with an exhibition system so far.

1.3. Modelling framework for sustainable co-management: basic principles

Exhibition systems typically include different components:

- Physical components: real estate (building assets, infrastructure, networks) and movable property (equipment, fittings, furniture systems).
- Intangible components: services and activities (permanent and temporary exhibitions, events, management, business).

The basis for defining an optimal management model of a complex exhibition system and to implement a decisional support tool stem from definition of the correct representation of the AS-IS scenario, defining the physical components, (buildings, service networks, utilities) as well as their complex interactions. The complexity of this analysis is clearly evident. As a specific example, the management of the sub-system *building* brings a set of technical problems closely related to the specific architectural and structural design, to the construction history and to the evolution of service requirements over time. In the case of Fiera del Levante (FdL), in particular, most of the

existing buildings were built more than 50 years ago, according to old building standards and technologies, and thence the actual features and performance levels may prevent the sustainable management of complex events. On the other side, an appropriate co-management platform needs an accurate and complete physical modeling of buildings, according to the different use conditions, whereas the analysis of criticalities, maintenance strategies and management models would require a clear understanding of existing information, which is rarely the case. In the case of old buildings, as those of FdL case, data retrieval and analysis is particularly difficult.

The assessment protocol required to build effective physical models (including all the structural, functional and plant components) becomes critical, and - at the same time - big data management strategy for interpreting information is needed.

The proposed co-management framework is based on a *multi-scale* and *multi-criteria* logic, with appropriate simplifying assumptions, due to two main points:

1. knowledge processes can rarely be performed in a single step: resources required are too large, especially if the building stock is extensive. Thence, it is necessary to proceed progressively, step-by-step, according to what we define here a *multi-scale* stepwise procedure.
2. The complex interaction of many different components and performance requirements needs a *multi-criteria* approach to take appropriate decisions, actions and intervention strategies. In a general perspective, besides the physical components, the performance assessment of the system should include the “intangible” ones, taking into account either the physical assessment with the co-management processes.

Within this context, the framework proposed is based on the use of BIM to set a knowledge framework and implement an assessment procedure at different scale of analysis. The rationale is to provide an innovative tool for the performance based assessment in a context of uncertainty and incomplete information. The framework allows to manage different “levels” of knowledge, starting from poor data and information (for the first screening and analysis), and progressively achieving more refined models with regard to object, associated data, assessment algorithms and procedures.

2. The Fiera del Levante Exhibition District: a multi-scale multi-variate system

The proposed approach has been focused on the case study of “Fiera del Levante”, a trade fair district extending over 280.000 m², composed by several buildings aged from 1929 to 2012, that host about thirty events (including international fair shows) throughout the year as well as conferences and/or exhibitions (Fig.1).

The peculiarity of FdL with respect to other exhibition system, that makes it a unique example in Italy, is the contemporary presence of several activities in a same area: permanent public and private business activities; possibility of several exhibitions with different scopes, congresses and entertainment events which result in an uncommon use profile. This determines a complex use scenario difficult to be managed according to sustainability criteria, due to the complex interactions of activities. The presence of multiple stakeholders makes the co-management a complex task to be performed by a human decision maker.

The complexity related to the management of Fiera del Levante exhibition system descends from the following elements:

- The FdL district results from a building stratification of more than one century (only one pavilion is a new building), with different building types and morphologies. Several pavilions were built as temporary structures, so they are far beyond their service life, and are also in the located in an aggressive marine environment. At the present, in fact, most of buildings are characterised by a relevant functional obsolescence;
- Contemporary presence of several different activities and users, involving the coexistence of ordinary exhibition events and several permanent business activities (tertiary, service, public offices, business, restaurants, entertainments). The use profile of the district and its facilities is highly diversified, and this determines complex interactions and sometime interferences, with possible potential criticalities for the sustainability;

- Management and organisational responsibility belongs to several different subjects, different from the owner, which is a further challenging task for the co-management.

The Fiera del Levante (Fig.1) is here thought as a living system, where structures and infrastructures are correlated to form subsystems which live autonomously, and interact when it is necessary. Management rules for use of spaces and fittings, service supply, building maintenance, use of plants and utilities form the “welcome features” of the FdL system. Finding their sustainable combination is not an easy job, considering that it severely affects the satisfaction of the end users. How to manage existing building assets, as well as how to guarantee the regular course of all the contemporary activities in the presence of thousands of visitors makes the decisional task a complex and slicky one.



Fig. 1. Schematic plan of the Exhibition District “Fiera del Levante” in Bari, Italy.

3. Modelling complex systems: the framework

The co-management framework here presented includes the solution of the following problems:

- Modelling the physical and logical components of the exhibition district (buildings; infrastructures; facilities) by a BIM approach aimed at the integrated management and inter-operability.
- Modular modelling of services, processes and of their interaction mechanisms.
- Defining the structure of data flows in order to gather information about requirements at the “micro” scale.
- Managing the previous database in order to analyze the time-history.
- Solving interface problems with information about the use of facilities and services, in order to propose improvements about the management of resources or about the characteristic process parameters.
- Developing algorithms for the interpretation and dynamic aggregation of models according to the variation of needs arising at a micro and/or macro scale.
- Developing flexible models for the analysis of the sustainability of services and process (considering the possible variations aggregations occurring over time).
- Development of optimization models to interface the results obtained from co-simulation with the results of analysis models in order to support the decision process of managers.+

For the sake of brevity, in the following we will give an idea about the difficulties previously pointed out in the specific case of the building components of the district.

3.1. Characterization and management of Building Components: BIM Modeling of the Exhibition District

The first critical point encountered in the research work is represented by the management of the building assets of the exhibition district. This physical sub-system is further made up of several components, each characterized by peculiar aspects (Table 1): requirements/performance targets; tools for the assessment of the performance level/vulnerability; definition of the possible action and intervention/mitigation strategy (ordinary maintenance

procedures; exceptional repair intervention; upgrade; retrofitting; demolition). Many critical points were found in the documentation about the building stock of the district: available documents are very few, and when they can be retrieved they are not systematically organized. Thence, a propaedeutic aspect of the research work is represented by a clear and systematic definition of the initial knowledge framework for the physical components and the related processes and services.

Table 1. Components of the sub-system “Building”, requirements, assessment procedures and possible actions

COMPONENT		PERFORMANCE REQUIREMENT/OBJECTIVE	ASSESSMENT	PROBLEM SOLVING
Structure	Economic and environmental sustainability, smart Building, Automation	Safety, resilience		Service maintenance; extraordinary interventions, demolition/rebuilding
Building skin; architectural elements and finishes		Functional efficiency and aesthetical value; energy efficiency	Knowledge; monitoring and control;	Ordinary maintenance, repair/replacement, upgrade
Technological elements and facilities		Safety, energy and environment efficiency smartness	Building Automation	Operational and managerial procedures, primary services. Ordinary maintenance, repair/replacement, upgrade

To this aim (according to the most recent and innovative research lines in the field of the application of software tools for the optimization of building analysis and management), a BIM framework has been adopted for the implementation of a representative digital model able to collect, organize and maintain information. The need to develop a systematic, reliable and dynamic model, easily query-able and upgradable, in the presence of inhomogeneous knowledge levels and disorganized data suggested an unconventional use of BIM. Different “scales” were implemented (see figure 2): besides the classical modelling of individual buildings, BIM has been also declined at an urban scale. In this way, it has been possible to structure a technical register to support a very flexible and dynamic procedure of data collection, management and model implementation.

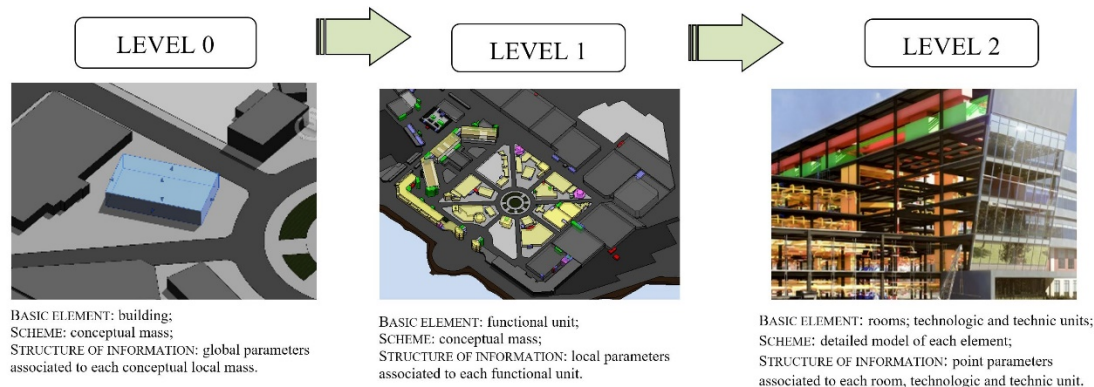


Fig. 2. Scheme of the Multi-scale BIM model for the Fiera del Levante Exhibition District.

The methodology (Fig. 2) was applied starting from a wider scale, and deploying in a set of levels, following a “multi-scale” approach. In the context of BIM approach, the term “level” identifies a set of elements and the information associated with them, characterized by a fixed degree of detail. Territorial and urban scales are associated with a “level 0” model, in which the basic element is the building, and the BIM schematization is a “mass”, to which available information is associated. At the scale of the building (level 0), it is possible to proceed according to two different phases: “level 1”, in which the building is modelled into its functional units (schematized by “masses”); “level 2” (knowing the appropriate detailed information), in which the technological elements of each

building are represented according to the typical BIM approach. A further goal was to test of the potentiality of the proposed multi-scale approach as an effective tool for the assessment and management of real estate assets with respect to different performance requirements. Two specific performance requirement targets were addressed: structural vulnerability and energy vulnerability, which were taken as two of significant reference components. The model is susceptible of further improvements to extend the whole framework.

A methodology for the integrated assessment of seismic and energy vulnerability at the urban scale was implemented. The assessment was based on the calculation of a Seismic Vulnerability index IV_S and an "Energy Vulnerability" index IV_E for each building. These indices are obtained by implementing a "level 1" analysis procedure.

The IV_S index is calculated through a procedure [6] based on the method of the Seismic Vulnerability Index. This method considers some simple parameters that summarize the performance characteristics of the building on the basis of relevant morpho-typological, constructive and structural data, to which a class of vulnerability is assigned, calculating a corresponding numerical value. In particular, for the purpose of this research, the evaluations concerned the following parameters: type and organization of the resisting system; quality of the resisting system; capacitive deficit; topographic condition and foundations of the buildings; type of floors; configuration in-plan; configuration in elevation; type of roof; non-structural elements vulnerability; maintenance level.

The input data for the previous evaluations are typically limited and very general (data collection is done with a brief inspection) and include: period of construction and subsequent interventions; geometric and morphological characteristics of the structural unit; general morphology of the site; maintenance level; damage of non-structural elements; exposure (importance of the building).

Finally, the numerical scores obtained for each parameter are combined by using appropriate weights. The result is normalized and the "relative" Seismic Vulnerability Index obtained assumes values within the interval $[0,1]$ (0 minimum seismic vulnerability; 1 maximum seismic vulnerability). The "Energy Vulnerability" Index IV_E can be calculated by using two different procedures: "Direct", in which the input data relate to building envelope and plant system; "Reverse", in which the input data are the energy consumptions.

For the present study, due to the difficulty of finding reliable consumption data, simple and direct calculation method was adopted [7]. This procedure, characterized by conceptual immediacy and simple application, allows the evaluation of the energy flows throughout building on a monthly basis. The required input data were: the climatic characteristics of the site, available standards and laws; geometric and thermo-physical characteristics of the elements and sub-components (if this features aren't known, they were extrapolated from documentation and/or surveys; otherwise hypotheses were put on the basis of standards, literature and experience). The data output is the primary energy supply for heating and cooling.

This methodology was implemented for the actual building and for a "Reference Building", which is defined as a building identical to the real one for geometry, orientation and climatic conditions, but with building envelope and plant system characterized by minimum performance standards. If the building has no plants, it is possible to envisage a plausible one, considering various aspects: type of available energy carrier; intended use; susceptibility of the building to the various types of plant; energy costs at the time of construction and context in which the building is located. The energy vulnerability index IVE proposed by the authors is the following:

$$IV_E = 1 - \frac{\text{Total energy demand reference building}}{\text{Total energy demand actual building}} \quad (1)$$

It allows to obtain a value in the range $[0, 1]$ (assuming the value 0 in case of $IV_E < 0$). The energy vulnerability index IV_E is a relative value for which 0 corresponds to a minimum vulnerability and 1 corresponds to the maximum vulnerability. IV_E and IV_S are univocally determined for each building, and they can be suitably combined to obtain a synthetic parameter defined "Integrated Evaluation Index" I_i which may express, in a synthetic manner and in relative terms, the presence of performance criticality within a homogeneous sample of buildings.

The integrated assessment was obtained by introducing correcting factors accounting to different variables that define the performance level. These factors depend on the type of evaluation and on the purpose of the analysis. These can have "tangible" or "intangible" nature and may be related to a number of evaluation filters: maintenance level and degradation (generally related to the construction period); exposure to hazardous agents and user profile, relating to the importance of the building; intervention capabilities for improvement or adaptation to current standards; etc.. In the proposed framework, we take into consideration the degree of difficulty and the level of invasiveness on building related to interventions for mitigation of seismic and energy vulnerability through an "index capacity for intervention" I_c . The structural interventions for the mitigation of the seismic vulnerability, in most cases, are characterized by higher constraints; consequently, the value of "index capacity for intervention" I_c assigned to IV_S is $I_{c,S} = 0.6$. The energy retrofit to reduce the consumptions and mitigate vulnerabilities, in most cases is characterized by lower constraints; consequently, the value of "index capacity for intervention" I_c assigned to IV_E is $I_{c,E} = 0.6$.

The "Integrated evaluation Index" I_i , which assumes values comprised between 0 and 1, is determined as follows:

$$I_i = \sqrt{I_{c,E}(IV_E)^2 + I_{c,S}(IV_S)^2} \quad (2)$$

It is directly proportional to the total vulnerability of the building, and it allows a rapid identification of critical situations by producing a "priority lists" in which "critical buildings" are highlighted, thence providing a useful tool for a general screening of the building stock and the planning of future rehabilitation strategies.

3.2. The framework: basic principles for the co-management of exhibition districts

The basic principles of the framework devised for supporting the co-management decision making are here briefly recalled. The following basic principles were adopted as basis: i) the Exhibition System should be considered as an *Adaptive Complex System*; ii) *collaborative management* and *adaptive capacity should be assured*; iii) each information used should take into account the inter-relation between different stakeholders. According to these, the framework consists of three steps:

Analysis

- Recognition and characterization of the stakeholders involved (owners, leaseholders, providers, permanent exhibitors, temporary exhibitors; etc.), of their needs and behaviours.
- Identification of the significant processes to be implemented in the platform.
- Mapping of the relationship among the different actors for the above mentioned processes.
- Analysis of the possible conflicts among stakeholders and of the corresponding causes.
- Assessment of the presence of possible opportunistic behaviors by some of the actors, which could penalize the global performance.
- Identification of the main risks that endanger the optimization of the global performance.

Design of the co-management features

- Participation of stakeholders: identifying who is involved in the co-management and to what extent for each process (active managing; information sharing; passive roles); choosing information sources; deciding which data should be shared on the platform and who can access them; scheduling the frequency of system update and of the participation of each stakeholder (regular, frequent, occasional, ...).
- Engagement of stakeholders: defining business contract in which the use of the negotiation is compulsory; defining mechanisms of reward/penalties, incentive/disincentive.
- Cooperation among stakeholders: defining mechanisms of risk/benefit sharing; designing negotiation procedures for achieving shared decisions; designing mechanisms for conflict solving; promoting trust among participants, eradicating opportunistic behaviours.

Design of an adaptive-complex management system characterized by self-organization, control of emergency situations, adaptiveness, learning capacity

- Identification, for each process, of the physical components that should be endowed with “intelligence” and definition of suitable tools.
- Definition which internal and external input shall activate each component of the system, and of the related control and monitoring tools.
- Design of early warning systems that will promptly notify high risk or conflictual situations, and request the intervention of the proper decision maker.
- Design of systems for measuring and monitoring the system performance, and of algorithms for the trial-and error learning.
- Classification of processes according to priority levels in relation to the stakeholder involved, in order to allow the management of emergency situations,
- Definition of procedures for the systematic revision of business contracts on the base of obtained results.

Design of a Cyber Physical System for the smart co-management

The final phase (that will represent the future developments of the research work) is aimed at the implementation of the integrated co-management model by means of an experimental research phase:

- design of a net of physical sensors for the monitoring of the relevant processes and services and integration within the platform;
- design of a system of social app for tracking the behavior of the users and integration within the platform.

4. Discussion and future works

Structures like Fiera del Levante Exhibition District are characterized by a complex interaction of services with many different stakeholders (visitors, providers, exhibitors, manager, ...). The coordination between the many different needs of the individual customer (micro) and the system (macro) represents a complex decisional task. The challenge for the management of the district was to promote information gathering and exchange for an effective decision making. The research group nurtured the idea of the development of a devoted platform for the co-management based on the proposed framework, endeavoring mobile smart technologies based on the active interaction with the single stakeholders and customers. The above mentioned steps of the framework can be in fact implemented by using specific techniques:

- Hybrid Modular Ontology Reasoning based on formal logics [8], which can guarantee an easy application of models and Anti-Logicist Framework for Design-Knowledge Representation [9], which can guarantee the unicity of aggregation of models.
- Big Data logic for the organization and analysis of data. The modelling of big quantity of data (Big Data) allows to create systems that can closely simulate the behaviour of physical systems, in order to detect the criticalities, make realistic predictions, support and facilitate the decision process. Big Data have three fundamental features: Variety, Velocity and Variability. In order to manage this type of data, it is necessary to use NoSQL database, which have very high performance and allow to operate a real time control.
- Biomimetic models for exergetic sustainability analysis of flows [10, 11].
- Bio-inspired algorithms for the optimization of sustainability [12] based on the analogy with systems studied within stochastic mechanics, characterized by high parameters, constraints and degree of freedom.
- Integration with smart grids for the collection, analysis and implementation of optimal solution for the waste of energy [13, 14, 15].

The possibility of balancing micro and macro requirements recalled above can be assured by the modular modelling of the services within the platform. This platform should be capable of expressing the interaction mechanisms of the different services, match the variation of the requirements at a micro level (customer) with those at the macro level (system) and correspondingly aggregate the models applied for the functional co-simulation. The phase of analysis provides a set of indexes, suggestions and warnings to be used as a support in the decisional process improving the sustainable management of the district.

At the present stage of development of the research work, the general framework of the physical model has been designed within the BIM ambient, implementing available data about building assets according to the multi-scale scheme outlined in par. 3.1. An innovative use of BIM for the assessment of the criticalities (structural and energetic vulnerability) of existing buildings at different scales of analysis has been implemented, applied to a first set of case studies. As concerns the co-management modelling framework, as described in par. 3, the analysis phase and the design of the structure of the co-management framework have been performed, identifying the available techniques and modelling tools.

The future phases of the research will provide the implementation of the different models and algorithms in the platform, the physical implementation of the cyber sensor net, and an experimental phase of benchmarking and application to case studies for testing and validation. The co-management platform should represent a tool characterized by swift adaptability to the evolution of the stakeholders' requirements (which could be temporary events, commercial activities, business activities, special events, ...), and at the same time able to define the optimal solutions by means of proper cost functions. Platform should provide also a guide for supporting the choices of the customers to achieve the desired optimal exhibition system configuration, by means of the implementation of social mobile tools for the dissemination and sharing of information.

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