

**Maintenance-Oriented Design in Architecture.**  
**A Decision Support System for the Evaluation of Maintenance Scenarios**  
**Through Bayesian Networks Use.**  
**A Case Study: the Headquarters of ING Groupe in Amsterdam**

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## **1 Introduction**

The design of buildings is increasingly characterized by a morphological, functional and technological complexity that requires, from coordination to control, maintenance and management of the entire life cycle, new skills to effectively implement a process in which the phases of design and construction are continuously intertwined over time.

This recent evolution has led, in the last decade, to a greater attention in design to the need for rigorous checks on the quality of the durability of buildings, generating a more careful design to prevent and manage the phenomena of obsolescence and degradation through the development of flexible construction solutions, maintainable and reversible, able to respond to the demands of a constantly changing world.

It has finally been recognized, not only among scholars of the subject, but also among architects that an essential requirement of "eco-responsible" design is the ability to predict and control the durability of buildings over time. There is, therefore, a growing interest in the development not only of theories and methods but also of specific tools capable of supporting the decision-making processes inherent in the various phases of the project, which involve the simultaneous adoption of multiple criteria that affect different fields of knowledge ranging from ergonomics to material science.

This study was developed at the Department of Architecture of Pescara and the Department of Energy, Systems, Territory and Construction Engineering of the University of Pisa as part of an experimental thesis that led to the implementation of a Decision Support System.

The objective of the work was to implement a tool capable of evaluating - in relation to the choices concerning the morphology of the building, the construction technologies, the materials and the design of the architectural elements - the levels of maintenance quality implemented in the various phases of the project, from the first phases, in which few relevant decisions are made, to the executive phase characterized by a multiplicity of choices.

The aim was to construct a tool in which the reliability of the evaluations was related to the

quantity and quality of the data that feeds the decision-making process, but which is also able to evaluate preliminary decisions based on the elements of choice that characterize the first phases of the project.

From the methodological point of view, we have worked in the direction of the construction of a system capable of managing the large number of variables that distinguish maintenance-oriented architectural design; a digital interrogable model useful to provide support for the automation of evaluation processes formalized on the basis of maintenance criteria that can be applied to the entire architectural organism or to a part of it, such as the façade.

The conceptual model has been defined through the construction and implementation of a Bayesian Network or a graphical system of probabilistic inference able to represent the set of stochastic variables and their conditional dependencies through the use of a direct acyclic graph. The insertion of the parameters of the single variables happens through the aid of an interface constituted by a spreadsheet in which the input data allow to reach a table of values for each node - variable of the model. Through the interrogation of the network it is therefore possible to evaluate through the expression of a synthetic index, a real overall rating of the different aspects that contribute to define the maintenance quality.

The use of Bayesian Networks, in the light of the analyses carried out on an experimental basis - exemplified here on the case study of ING Groupe headquarters - for the ability to control a multitude of factors linked to the durability of materials, the morphology of systems and ease of intervention, seems capable of generating useful, effective and expandable tools to support the design decision-making process

Thanks to the setting of the method, based on an ontology of several variables closely correlated to each other through a web of causal relationships, the system allows to determine the impact that determined, chosen from the point of view of maintainability, bring to the project allowing to establish what attention should be paid to the estimates of probability to obtain certain services of interest or at the same time what corrective actions are essential to be taken.

Future developments in the research of the SSD model are oriented towards the integration of cost parameters for a more complete and effective evaluation and comparison of alternative intervention scenarios.

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