KNOWLEDGE MANAGEMENT IN COSTRUCTIONS: AN APPLICATION IN THE FIELD OF ENERGY CONTROL

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Abstract

The growing complexity of the building process reaches high levels in Public Works, for which the Public Administrations (PA) still prove to be rather oriented towards a process of emergency management than towards an efficacy and efficiency policy of processes. The variety of the different subjects involved in carrying out of the building processes, makes the development of integration and cooperation instruments necessary. Through the present work, we suggest a solution to such issues: focusing on Knowledge Management (KM) techniques means to rationally organize the considerable quantity of data/information and to capitalize the consolidated knowledge. A PA aiming at improving the management of the building processes can implement an internal knowledge map to establish and/or make explicit the company standard procedures. The article reports the outcomes of a theoretical research, a work-in-progress, in which the knowledge management techniques are combined with possible applications related to the building field, and in particular to the energy control aspects of the buildings. However, in order to deal with the problem it is necessary to define both a common knowledge management platform and a new procedure to allow the interrelation among the involved actors. The first part of the article focuses on the definition of the basic unit (elementary product) of the internal knowledge map of the PA, and then it proposes a possible process of interaction with it. The article continues highlighting that the use of the knowledge map allows a re-examination of the whole public building process fundamentally improving the management of the energy efficiency of the buildings. In the last part, the article details a hypothesis of datum structuring concerning the energy control of the buildings inside the knowledge map. The outcome of the work is a first contribution to the implementation of an instrument to collect and share the specific knowledge of the PA. Therefore such an instrument can rationalize the whole public building process optimizing the energy management of the public building property.

The technological infrastructure will be a crucial element in order to operate and run the knowledge map: a software platform that, operating in a shared and cooperative environment, supports the elicitation and sharing of the structured knowledge.

Keywords: knowledge management, building process, energy control.

1. INTRODUCTION

The growing complexity of the building process reaches high levels in Public Works, for which the Public Administrations (PA) still prove to be rather oriented towards a process of emergency management than towards an efficacy and efficiency policy of processes. Carrying out a public work is a demanding and binding project that combines a high number of variables and requirements often contrasting and conflicting one another. The variety of the different subjects involved in the drawing up and carrying out processes of the public policies, makes the development of new integration, communication and cooperation channels necessary. The present models of interaction among the actors of the public contract (Public Administrations, Designers, Building Contractors) are no longer suitable to the context in which the subjects work. There is a need of new and supporting solutions to correctly and effectively transmit information. A reply to such issues is to turn to Knowledge Management (KM) techniques that, through a rational organization of the considerable quantity of data/information[1][2], and through a capitalization of the consolidated knowledge, allow the development of a protocol for
the communication[3] and the coordination[4] of the involved subjects. In the Public Administrations, the implementation of a KM policy supports the choosing process in relation to public buildings during the designing, carrying out, and management stages. Moreover, the introduction of KM instruments in the involved subjects’ organization, favours and facilitates the definition of a common code and of a common interface. The KM assumes the form of a discipline defined as follows: “the Knowledge Management is the systematic, explicit and deliberate organization, application and renewal of a company internal knowledge, aiming at maximizing the effectiveness of the cognitive ground and of the related advantages” [5]. Taking into consideration this definition, it is easily understandable that including a KM policy in an organization implies considering knowledge as a key resource to develop, capitalize, and share and which the future of the operating strategy will be founded on. “Knowledge is the information that changes and modifies the organization, making the agent capable of new and/or effective actions” [Peter Drucker]. One of the KM instruments is the knowledge map: developing a knowledge map means rationalizing and making explicit the dynamics and the know-how structure in a company organization. Therefore, the first step in order to implement a KM system is the definition of the map contents, schemes, and structures aiming at the insertion and at the consequent availability of the knowledge collected by all the involved subjects. There is the need of defining a basic unit for the knowledge maps of the subjects involved in the building process and, therefore, we suggest the concept of elementary product, of which we present a clear and complete definition in the following paragraph.

2. FROM THE FEASIBLE PROJECT TO THE “ELEMENTARY PRODUCT”

Describing the building object as a tree structure with several levels, following the top-down technique[6], the outcome is a representation that, cascading defines all its components to the most elementary ones, in details. The building object is resolved into three elements, called macro products. They are further subdivided into products and by-products, progressively less complex, to the level of desired decomposition. Such a procedure allow to work on smaller and smaller portions, more easily controllable and governable, coordinated by a productive simulation. The levels at the base of the built hierarchical tree show an in-depth and detailed definition of the work in the carrying out of the final product; moreover, they have an identification code that highlights their sequential order in the structure.

![TREE-LIKE DECOMPOSITION (P.B.S.)](image)

The construction of the PBS and its efficacy in a process, are directly influenced by the level of accuracy used to identify all the parts of the building object. The decomposition process finishes when the required level of appropriate accuracy is reached. It is important to remember that the decomposition level varies according to the characteristics of the work to carry out. In fact it is correct to say that the PBS can be divided into any number of levels, according to the
intervention complexity, nevertheless, if the destructuring is extreme, it is difficult to keep track of the work general state, particularly if it has a long-term planning. The terminal levels of the decomposition include those products that are:

- Significant in the specificity of the requirements;
- Measurable and verifiable, because both the variables and the parameters that define the product to carry out, allow the exact and univocal surveying of the progress meter;
- Manageable, because susceptible to the allocation of the resources needed to their production;
- Identifiable, because assignable to a determinate subject, that, from that moment on, will be responsible for the outcomes.

The products that meet these characteristics are defined elementary products. [7][8]

![Hierarchical Decomposition Diagram](image)

The decomposition level, which the elementary product belongs to, allows an effective management and control of the process in regard to the economic, temporal, and quality aspects.

A further decomposition would subdivide the elementary product in its constituent elements, leading to a loss of its identity as a building component, which is the elementary product’s primary characteristic. The definition of traditional feasible project is in contrast with the concept of robust project, which is made up of the totality of the elementary products singled out for the specific building object and correlated by a productive simulation. So the project becomes the conception of a building object in relation to the production possibilities and methods, and to its employment and maintenance. This means that, starting from the PBS, the interrelations among the different products are singled out making explicit the connection typology and the conditionings during the object carrying out. Therefore the robust project does not only take the shape of the sum of elementary products, but also the shape of an organized structure of elementary products.

3. **Knowledge Maps in the Public Building Process**
The defined elementary product represents the basic unit of the knowledge maps of the different actors of the public building process. Each map is oriented towards different needs and requirements, and in each one of them the knowledge related to various aspects of the same elementary product is recorded and capitalized.

**KNOWLEDGE MAP OF THE DESIGNER**

**KNOWLEDGE MAP OF THE BUILDING CONTRACTORS**

**CONSTRUCTED BUILDING**

**KNOWLEDGE MAP OF THE PUBLIC ADMINISTRATION**

Organized data of the map of the PA

**VIRTUAL MODEL OF THE BUILDING**

(Non-stop updating)

**ROBUST PROJECT**

(Planning model)

**PICTURE 3**

THE CONTENTS OF THE ORGANIZED DATUM IN THE MAP OF THE PA

Going into details:

- **The knowledge map of the designer** includes the elementary products defined in terms of performing and productive aspects. Through the support of the knowledge map, the designer identifies the elementary products that supply the fittest solution to meet the requirements table made explicit by the PA, according to the robust project.

- **The knowledge map of the building contractors** includes the elementary products defined in the purely building aspects: the building contractors aim at associating each elementary product to the activities required to its accomplishment, rationalizing both the resources and the building time and capitalizing the knowledge related to the outcomes[9];

- **The knowledge map of the PA** also proves to be structured on an elementary product basis. It supports the queries related to the decision-making stage, to the project evaluations, and to the control of the procedures to select the building contractors and to construct the building. Further queries also allow the retrieval of management and maintenance aspects of the building in use.

The graph shows that, with the progress of the public building process, the map of the PA progressively grows richer and richer of contents registering:

- The defined requirement table;
- The documents preliminary to the explicit designing;
- What defined by the robust project (organized in a virtual model of the building);
- What capitalized during the work carrying out, and according to the virtual model updating;
- Data, information, and knowledge required to the effective management and maintenance of the buildings;
- Knowledge that concerns the updating of the virtual model of the building, and that is related to the interventions carried out on it after the accomplishment of the construction.

**3.1 The Energy Efficiency of the Public Buildings**

An optimum and excellent employment of the previously illustrated map of the PA, is fully realized in the management of the energy aspects of the public building property. The increased environmental sensitivity and the progressive exhaustion of the traditional energy sources has produced a high rise of the costs of such sources[10]. At global level the developed measures consist in policies of containment[11] focused on binding regulations which also concern the designing and the carrying out of the buildings. At local level there are different outcomes in the research field [12]. At the moment a lot of attention is given both to alternative energy sources
and, in the building production field, to the development of new construction technologies and new production cycles that are oriented towards cost minimization in the heating and cooling system of the building. The target is limiting and controlling the energy requirements in order to reduce the consumption of energy while keeping the thermic comfort conditions unchanged. The energy efficiency is a key factor in the construction and management of public properties (schools, hospitals, theatres, etc.): their size and the developed activities are elements that classify such buildings as energy eaters. At the moment the PA has not reached an acceptable control level of the energy efficiency aspects for public buildings mainly because of:

- Poor consolidated knowledge;
- High quantity of information, which are redundant, neither up-to-date nor correlated;
- Poor integration among the subjects of the process.

4. THE MODEL OF THE PUBLIC BUILDING PROCESS
In order to achieve a considerable improvement in the energy efficiency management, it is absolutely necessary to re-examine the whole process and to invest on up-to-date and progressive forms of control of the numerous variables at stake. Furthermore a cultural growth of all the involved subjects is to be hoped. In this section we propose a model of the public building process that aims at these targets.

4.1 Time ($T_1$): Decision-Making and Planning Stages
The PA makes explicit the requirements table which is created according to heterogeneous data collected and analyzed by the different subjects of the public organization, also using some data related to existing buildings. Such data, combined with the knowledge map, allow the use of introductory documents that, providing precise characteristics on the building components, enable the definition of a fixed thermic balance of the public building. Thanks to such information, the designer elaborates a robust project, which is the sum of interrelated elementary products, whose technical characteristics respect the bonds and satisfy the particular explicit requirements. The carrying out of the robust project through virtual data processing models allows, thanks to functional simulations, the control of the energy balance and of such bonds. At this stage the use of elementary products highly facilitates the dialogue between the designer and the PA: the replacement of one of them in the model permits the comprehensive control of the building thermic balance at any time. According to the contents of the elaborated robust project, the following activities will be implemented the updating of the knowledge map of the designer, the updating of the knowledge map of the PA, the starting up of the implementation process.

4.2 Time ($T_2$): Building Stage
After concluding the planning stage and after capitalizing the robust project in the knowledge map of the PA, the next step consists in querying the knowledge map of the PA in order to rapidly obtain data, information, and knowledge to define a call for tenders for the building object to carry out. The building contractors that submit a tender, make a technical and economic offer. Therefore they identify all the activities required to implement and carry out each elementary product, so the building itself. Using company knowledge maps it is possible to define the nature, the importance, the commitment of resources for the specific contract, the production techniques, the term of work, and the total costs. The capability of a company to process the data, and the knowledge used and produced during its own activity, and the capability to capitalize and reuse them, are the key elements to develop and favour the competitiveness of a company organization. Through the models of company process called Best Practice, capitalized in-itinere, the company makes use of the a priori known knowledge in order to correctly estimate the interventions to carry out. Carrying out the work, the map of the PA has to be constantly updated. The knowledge related to the technical solutions and to the materials used in the building process have to be capitalized in the virtual model, also if they vary from what provided in the robust project. The knowledge of the map is not only an up-to-date and reliable source, but also a starting point to manage and maintain the whole public building property of the PA.

4.3 Time ($T_3$): Management and Maintenance of the Public Building Property of the PA
The dilapidated state of the buildings makes the planning of ordinary and/or extraordinary maintenance necessary. Such a necessity becomes of primary importance considering that the energy efficiency of the building system is heavily influenced by the condition of its components (elementary products); it follows that the registration of all the information connected to each particular building gives constant reliability and dynamism to the map of the PA. Therefore the
map proves to be the instrument that, through various querying procedures, permits an effective
technical control during the building use and an economic planning for the building maintenance
and a maintenance scheduling. Through a distinct access to the capitalized knowledge, the
different operators of the PA will be able to develop specific management programs.

5. STRUCTURE OF THE DATUM OF THE KNOWLEDGE MAP OF THE PA
OUTLINE OF THE CORRELATIONS AMONG THE DATA OF THE KNOWLEDGE MAP

Going deeply into what has been defined as the organization stage of the PA knowledge, the above scheme represents a first hypothesis of knowledge map structuring in the energy control field. The knowledge is considered as different elementary products of the interventions to carry out that, from time to time, the PA has to deal with. Each elementary product is associated with two fields: one is linked to the parameters that identify, in the project, the elementary product itself; the other is linked to the parameters that identify it in the carried out building. For each elementary product, such an approach allows the registration of the significance knowledge both implied in the project, and linked to what has been really carried out. Therefore, it is also possible to register the information related to the needed periodical interventions to guarantee a correct use and a suitable maintenance of the building for which the approach has been developed. The implementation of the above knowledge will be carried out registering various heterogeneous parameters; consequently there is the need of defining an elementary record which in the basic unit of the map: inside it, the links and relations among the single parameters will be structured.

A query - through elementary products - of the knowledge map of the PA, provides both data and synthesis information concerning the energy control of a single part of the building. In fact, on the basis of the elementary product characteristics, the knowledge - registered in the form of an elementary product - permits that a new configuration of its components has not to be redefined every time it is used. Such a methodology allows, through a dynamic fruition of the information related to the heat loss due to a fixed elementary product, to pair outcomes of different elementary products in order to evaluate the thermal bridges.

The quantity of heat dispersed in the thermal bridges can be quantified through a calculating tool. The operation is not precise because of the difficulties concerning the synthesis of the different interfaces between the building elements. On the contrary, saving the data related to each single record – or elementary product – in a knowledge map allows a fast and effective control in the decision making process of the different energy aspects of the building, during both the planning, and management level.

Thanks to the first analyses of some practical applications of the energy aspects carried out on a mathematical model of some buildings, the heat loss, owned to thermal bridges, has been quantified around 40%. The reported structure of the records permits the use of knowledge maps that can rapidly define the heat loss aspects of single parts or of whole buildings.

6. CONCLUSION

The present work, based on the implementation of a knowledge management system in the public building process field, has led to the definition of an instrument to collect and share the peculiar knowledge of the PA. Thanks to the use of the map contents, the PA will be able to make use of the known contents to reaffirm its role as the coordinator of the whole carrying out process of the public work, from its conceiving to the following stages of carrying out, use, and maintenance. Therefore it will be possible to optimize the management of the energy aspects of the whole public building property. The development of the concept of elementary product as the basic unit of the knowledge maps has led to a common protocol through which the efforts of all the subjects involved in the particular building process can be coordinated. Facilitating a cooperative and dynamic relation among them is the expected outcome.

Consequently, the advantages of such an approach can be summarized as follows:
• The support to the energy efficiency planning in each new building work, with the possibility to access a historical database of similar successful interventions; in this way the margin of error estimating the energy balance of the future buildings is reduced;
• The accomplishment of a real and concrete coordination among the different subjects of the public building process;
• The implementation of an instrument to plan the maintenance of the buildings, in order to guarantee a constant energy efficiency.

It is fundamental to clarify that the proposed project refers to new public buildings and therefore the existing public building property of the PA is excluded from what has been developed up to now. As a matter of fact an effective containment policy of the energy consumption also provides for the requalification of the existing buildings, that at the moment are the real energy eaters. The poor and lacking efficiency of the existing public building property is due to the fact that most part of it was built when no regulations on energy efficiency provided for such cases, and to time deterioration that reduced the building system efficiency and that it is caused by lack of maintenance.

The future plans related to what has been developed in the present work show that the knowledge maps will prove to be the instrument to capitalize the knowledge through virtual models of the existing public building property. The implementation of such models – making use of the data, of the related management software, and of the defined elementary products - will lead to the definition of a complete and functional knowledge map of the PA, capable of applying effective policies of energy efficiency.

The development of the concept of elementary product is therefore linked to the implementation of the technological infrastructure to operate and run the knowledge map of the PA: a software platform that, operating in a shared and cooperative environment, supports the elicitation and sharing of the structured knowledge.

7. REFERENCES


