This paper presents a research concerning the theme of the support didactic tools for a maintenance oriented design. The work takes a starting point in two remarks: the first is the importance of maintainability requirements prevision for the correct planning of a project and for the formulation of maintenance strategies; the second is the lack of information (examples, references, laws, quality and performance plans) easily available for students and designers.

The tool that has been pointed out has the aim to provide the information - belonging to different categories of knowledge - useful for a maintainability conscious design, according the free navigation modalities typical of hypertextual applications.

Starting from a matrix that associates building subsistems and maintainability requirements the student has the possibility to navigate into a network in which it is possible to have information about: european laws concerning maintenance, examples (drawings, pictures and description) of architectures and of industrial components that regard particular maintainability solutions and a plan in which are schematized the appropriate dimensions and the morphological configurations for the maintenance activities.

This hypertextual didactic tool has two different educational applications:
1) during design training courses, it can support in self-training about maintenance aspects;
2) it can become a specialistic module inside an integrated CAAD system developed to combine the graphic representation with different performances evaluations.
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Objectives

The objective of the hypertextual didactic tool is to support the development of maintainability conscious projects. This tool can be used either by students during design training-courses or by architects. The didactic tool provides data about maintenance according to five aims:

1) to collect and organize all the heterogeneous information that it is necessary to know in the conception of a project and in the development of construction details. The tools are guide-lines for design and for self-learning;
2) to evaluate and self-evaluate the maintainability of projects and construction details and to select the solutions easier to be maintained;
3) to extract information useful for the realization of check-lists and of operative tools like maintenance manuals and maintenance plans;
4) to spread the maintenance culture through design training-courses;
5) to include operative problems inside the conception of the project.

The didactic functions of the hypertextual tool

The hypertextual didactic tool has four functions:

1) the problem setting. It has to provide the knowledges necessary to identify, to formalize, to systematize and to organize the design problems connected with maintenance operations;
2) the problem solving. It has to provide the information and indications (optimal dimensions, morphological configurations, disassembling and assembling schemes, and so on) necessary to solve the maintenance problems;
3) the self-learning. The students can develope different and personalized learning paths according to their specific design needs and interests;
4) the teaching support. The teachers can prepare lessons or didactic modules realized on the base of the different design phases in which the students are engaged.

The requirements of the didactic tool

The tool has been developed according to a list of requirements depending on the established didactic aims and functions:

- to use the tool without the support of manuals or the need of training;
- to use the tool according to the associative cognitive paths typical of the design activities;
- to move freely and speedly inside informative networks without predefined paths;
- to add new data and new categories of knowledge in the time;
- to associate freely different forms of information: schemes, different scales drawings, photographs, descriptive texts, check-lists, diagrams;
- to associate freely different categories of maintenance information: design and operative instructions, national and international regulations, assembling and disassembling schemes, repairing modalities, ergonomic dimensions, examples of architectures and construction solutions, references of building components selected between market products;
- to associate typological and technological configurations to specific maintainability subrequirements (accessibility; diagnosticability; modular structure; components interchange, assembling and disassembling; standardization; possibility to be cleaned; possibility to isolate elements and parts);
- to extract morphological rules useful for the architectural design;
- to extract precise dimensional and geometrical data useful for the details design;

The hypertextual environment (software Toolbook) appears to be the most appropriate for these requirements because it allows:
- to navigate freely and easily inside informative networks;
- to process and connect many and heterogeneous information through key-words;
- to associate images and texts.

Didactic and knowledge transfer

In the last years an intense debate about building maintenance has been carried on inside different contests - universities, research centers, voluntaristic regulations, real estate agents - and a complex scenery of organizative models, skills and maintenance services is emerging. But it is to stress the fact that as far as design process very few operative maintainability instructions have been pointed out till now. Nowadays there is a lack of information for architectural designers, even if the need is more and more growing: real estates agents and maintenance managers are realizing that a significant rate of maintenance costs and of depreciation of the buildings is due to design mistakes; the recent laws about public works include maintenance plans between project documents; changes in the building market are drawing attention to the intrinsic quality of the building and to their conditions of preservation; the users are becoming more and more conscious of quality requirements. This scenery points out a double need of competences: on one side designers able to develop maintainability conscious projects; on the other side project maintenance managers, that is to say specialists operating inside design team, able to support the designers suggesting and verifying architectural configurations and details, simulating maintenance operations on the proposed solutions, interfacing with specialists,
interacting with components producers and suppliers, realizing
maintenence manual and plans.
Many of the information necessary to the education of these competences
are spread inside different sectors.
To collect, to generalize and to make usable many of these information
inside an informatic support system for the education, a transfer
operation has been conduct extracting knowledge from different fields:
1) from industry. The industrial sectors (in particular petrolchimic,
aeronautical and military), for their needs of availability of the devices
and of safety, economy, efficiency of the processes, have been
researching for over thirty years on the theme of planned maintenance
in order to control, to predict and to reduce the distribution of
downtimes, the Mean Time To Repair and the Mean Time Between
Failure.
Concepts like reliability, durability and maintainability have been
developed inside industrial and militar sectors and than tranferred to
the building sector. In particular the military sector, owing to its
mission, has developed important metodology to establish design
concept for high maintainability systems.
A transfer work has been conduct from some Military Standards
Handbooks (MIL-STD 470 Maintainability Management of DOD
systems; MIL-STD 471 Maintainability Demonstration; MIL-STD 472
Maintainability Prediction Handbook; MIL-STD 470
Maintainability Terms and Definitions) extracting, semplifing and
organizing information useful for architectural designers, such as the
minimum dimensions of elements and spaces for maintenance
operations, assembly and disassembly sequences and the relations and
connections between elements and parts of the systems;
2) from regulations. The instructions related to minimum dimensions are
extracted also from standards dealing with mechanical and etlectrical
sectors (such as Afnor, British Standars, CEI standards);
3) from tertiary building sector. Many typological and technological
solutions adopted inside complex tertiary buildings for easy and rapid
maintenance activities (external and internal spaces for the
maintenance activities, accessibility and inspection of systems,
dimensions of maintenance equipment, and so on) are assumed in
their basic concepts to extract general instructions useful also for other
building sectors (for instance the residential);
4) from case-studies. The same transfer operation has been carried on
buildings in which the maintenance problems had been treated with
particular attention.
The information extracted from these fields have been transfered and
organized as reported in fig.1.

The hypertextual didactic tool structure
All the information collected in the hypertextual didactic tool structure
are extracted and consulted through a principal matrix (fig.2) that
connects columns reporting the subsystems (which form the building)
and rows reporting the subrequirements (which constitute the
maintainability requirement) and that represents the entry to the hypertextual navigation (fig.3).

At each intersection of columns and rows it is possible to come to a deeper layer of selection in which at first to select technological units (for instance vertical envelope, horizontal superior envelope, horizontal inferior envelope) and secondly to choose between dry assembled and not dry assembled systems and components (this double option is due to the two different maintenance behaviours).

At this point the navigation inside the informative network takes place. The user can extract information on the base of three different categories of knowledge, and at the same time can realize his path going cross these three categories by key-words that connect texts and images.

1) Regulations (fig.4). It is possible to obtain the references of regulation and standards concerning maintainability and maintenance operations either from building sector or from industry sector. Through keywords it is possible either to read abstracts of the specific standards or to visualize operating schemes and images of typological or technological configurations;

2) Maintainability instructions (fig.5). Instructions are sintetized to give check-list regarding the aspects that have to be considered. Through key-words it is possible either to reach more detailed explanations, or to visualize schemes, dimensional instructions and images (fig.6), or to read regulations titles and abstracts;

3) Examples. Typological (fig.7) and technological (fig.8) instructions can be visualized looking at photographs and drawings of buildings and components. Each of these images are completed by description in which the maintainability solutions are described. Through keywords it is possible to enter the other information categories.

Conclusions

The hypertextual didactic tool is nowadays completed and after a test phase it will be available for the students of some Construction Laboratories of the Faculty of Architecture of Milan.

In this moment the Faculty of Architecture of Milan is experimenting a new studies organization in which architecture project has assumed a fundamental role as means for the transmission of knowledge. An intense debate is nowadays carried on about innovative didactic models and the most appropriate methodologies and tools for the teaching of technological knowledge inside the design training courses.

The aim is to create an articulate environment of informatic tools; each tool can regard a particular aspect of design knowledge. The student can set his personal and complex scenery of design problems, look for solutions and for evaluations by connecting the different tools and extracting specific information.

The tool that we have presented can be an example of these tools through which the students can act auto-reflexive processes: the design activity becomes not only the occasion to realize a project, but also to learn and to reflect about the design method.
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Fig. 1. The transfer process

Fig. 2. The principal matrix
Fig. 3. The hypertextual didactic tool structure

Figure 4. Example of the regulations references that it is possible to consult through the hypertextual tool.
The highlighted words are key-words that allow to go either to the regulations texts or to other information categories and sections in which the same themes are treated.
Figure 5. Example of instructions and schemes regarding typological and dimensional aspects. Through key-words it is possible to reach more detailed explanations (fig.6) or examples of buildings (fig.7) in which the described solutions are present.

Figure 6. Example of ergonomic informations useful for the configuration and the dimentioning of typological and technological solutions.
Figure 7. Example of architectures in which are presented some typological solutions relating to the analyzed subrequirement and subsystem. Through key-words it is possible either to have more detailed informations about the architecture or to enter the other information categories.
Figure 8. Example of components in which are presents some technological solutions relating to the analyzed subrequirement and subsystem. Through key-words it is possible either to have more detailed informations about the component elements or to enter the other information cathegories.