Development of a decision support system for bamboo building design

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ABSTRACT

Bamboo, the fastest growing woody plant, is used as a common building material in bamboo-growing countries and recently also in non-bamboo-growing countries. In spite of this fact, building designers or users of a building have problems using bamboo as a building material since they lack information and guidance in how to use bamboo. This paper proposes a decision support system (DSS) that might be useful for designers when they design a bamboo building. It presents an early-stage design process of bamboo building and the development of a DSS. The architecture of this system is based on the theory of DSS and knowledge of bamboo that should be integrated in the design process of bamboo building. So there are three components: a DSS, design process, and knowledge of bamboo. The process starts with determination of the building system, database construction of bamboo building parts, and the rule for using bamboo in each building part. The process focuses on systematisation of each design stage and integration of the building parts to construct a monolith bamboo building. The purpose of systematisation is to offer designers a means of categorising problem solving during the design process in terms of, for example, assumption, criteria, alternatives, and acceptable solutions.

1 INTRODUCTION

Bamboo is the fastest growing woody plant known to mankind. It has more than 1,000 varieties in the world, which with diameters ranging from two centimetres to twenty centimetres and heights varying from three to thirty meters. It has excellent technical properties, i.e. its stiffness ratio is better than steel, and its strength ratio as high as steel (Janssen, 1981). It is small wonder that bamboo is widely used traditionally as a building material in bamboo growing countries.

There are many ways to use bamboo as building material, i.e. directly in its original state of culms, split and woven, thiny-sliced and woven into mats, and also recently used as laminated bamboo which is known as plybamboo. It can be even used for almost any part of the house. Unfortunately there is still a problem in how to design building parts that are based on bamboo materials, since the designer does not know exactly how to use them. In such a case the designer needs a system to support his/her decision making during his/her designing process of the bamboo building. This paper is concerned with the development of a Decision Support System (DSS)
that can be applied to bamboo building design activities. The role of DSS in the whole design process, construction and maintenance can be seen in figure 1.

![Diagram showing the role of DSS in the whole design process, construction and maintenance of a bamboo building]

Figure 1: The role of DSS in the whole design process, construction and maintenance of a bamboo building

Focused on the development of a DSS, a general view of the system should be formulated that is explicitly based on the existing problems in the design process and aspects of the building, such as the user requirements, building forms, functions and behaviours (Zamanian, 1999). In relation to this, Celebi (1998) asserts that building functions and tasks should be considered as well. The user requirements are related to type of users and they might be an owner, a designer, a construction company, a maintenance company, or the occupant. These aspects will be used to describe the building as a system. The building system can be developed by the composition of all of the system into sub-system that have interrelationships with other sub-systems. All parts of the building elements that consist of sub-systems should be considered as part of an integrated system. Celebi (1998) describes “integration” as the incorporation of diverse parts or groups into a well-ordered whole. In other words, integration defines the relation of parts within the whole. As where Celebi's model concerns the building process in general, this paper would like to adapt it to a bamboo building system.
2 BAMBOO BUILDING SYSTEM

The building system is usually formed by a combination of a great deal of complex knowledge and components with today's technological possibilities. To achieve a building adequate performance, the coordination, organization and supervision of the building process should be carried out by an architect. These aspects here are the elements of sub-systems which form the building system of an architectural product. The definition characterises the sub-system components in concrete terminology is preventing the building system from being expressed as important complexities and contradictions -even if different integration principles and different architectural approaches are followed. According to Celebi (1998), the sub-systems are considered as a “whole”, they actually are integrated to form a “greater whole”. That is to say, they all form the “wholeness of the building system”. In the same way, bamboo building, which is performed with new building systems and construction techniques, is being improved by opportunities provided by the improvement of the traditional technology and by the development of bamboo industrialisation. Another views the building product as a man-made environment. Different analysis principles need to be determined for each sub-system, as well as the relationships between analysed systems, components, and the integration possibilities of them- need to be determined. In addition, the system should describe the criteria that must be met before problem-solving can be effective. Solution provided by this system may suggest performance values to the designers or users.

According to Osburn (1991), the required performance criteria for the building can be described as follows:

a. easy maintenance the wholeness of the building, in the face of the decrease of the mechanical and physical qualities over time (appearance, strength and stability, and physical deterioration),
b. maximum comfort of the occupants (thermal comfort, sound control, lighting, and ventilation),
c. life span (durability),
d. environmental aspects (weather exclusion),
e. materials and their characteristics,
f. safety issues (security and fire protection),
g. physical performance,
h. health factors and sanitation,
i. cost.

According to the criteria above, the wholeness of the building should always be reliable for its lifecycle. Therefore, the aim of integration is to unify the building sub-systems so as to function harmoniously and appropriately. As a result, they may meet the maximum building performance criteria (Celebi 1998) and contribute to the efficiency of energy, lifetime and material. In attaining the wholeness of the building, the designer can be guided by the taxonomy of concepts in architecture (Bax and Trum 1993) and the appropriate DSS. Figure 2 shows the proposal of a bamboo
building system that is based on the building functions and sub functions according to this taxonomy of concepts and the DSS.

![Diagram of Bamboo Building System](image)

**Figure 2: Proposal of bamboo building system**

3 DECISION SUPPORT SYSTEM

Problems of bamboo building design can be described as follow: lack of building code and standard, the image of bamboo as a poor man's housing material, and no a systematic design guidance. In order to solve these problems, we have to develop a systematic design guidance developed as a design decision support system (DDSS) for bamboo building. The decision support system in figure 2 can be used as a model of DDSS.

Solving problems in Bamboo building design requires a system based on bamboo knowledge, and databases of bamboo, building structure, and building construction. These databases should be integrated into a system to support design activities which is called a DDSS. According to Zutphen (1999), a decision support system (DSS) has components as follows: Databases, database management, knowledge management, rule base, reasoning engine and user interface. (See figure 3)

The design of databases in the DDSS can be divided into 4 steps, i.e. user requirements, conceptual design, logical database design and physical design (Awad
User requirements are provided by information/data collecting, and data analysis.

![Diagram of DSS Components](image)

Figure 3: **Components of a DSS**

Conceptual design is constructed with the Power Designer Program. In this program we can construct a conceptual data model and a physical data model. Output of the physical data model can be used to build databases in the DDSS program. The process of conceptual design in the conceptual data model can be seen in figure 4. In this process there are three steps, i.e. making design specification, establishing the function structure and establishing the schemes.

The databases are used as data knowledge bases of bamboo building. The DSS is built as a computer program, so an interface is needed to connect the databases and the main program: the database management. As figure 3 shows, two interfaces can be distinguished. The database management functions as the interface between database and main program and finally a user interface.

4 STRUCTURE OF DSS

The structure of a DSS can be based on the structure offered by Archer (1969), which attempt to provide a logical and systematic model of the design process. This model
allows designers to choose which type of decision to make: strategical, tactical, or optimisational, and to find the most acceptable solution for their problems at that level.

(adapted from Awad 1992)

Figure 4: Steps in database design

The level structure of a DSS can thus be seen as a three-dimensional model (Hill, in de Groot 1999) as described in figure 5. It contains a scale of six Human System Levels, i.e. basic, functional, economic, local, ecological and strategic levels. At these levels, factors are assessed such as strength and stability, security, durability, comfort, dimensional suitability, weather exclusion, sound control, thermal comfort, fire protection, sanitation, security, lighting and ventilating, and appearance. This scale may be matched with the taxonomy of concepts in architecture (Bax and Trum, 1993). On a second axis of the model, the Architectural System, a certain component of the building process may be assessed according to the workplace and building criteria to be met by the designer, which are described at a certain level of that scale. At the third scale of levels, that of the Building System, the DSS can target any of the six levels ranging from stuff to site aspects. A simple calculation shows us that this three-dimensional model offers no less than hundred eighty three-way decision 'cubes'. A cube of decision will offer a solution at any targeted decision level, and it is possible to make successive decision steps in the design process, moving from one cube to
another in the domain levels. Projected on the specific process of bamboo building, this model will offer solutions at the cube positions indicated by the shaded levels in figure 5.

5 RELATIONS BETWEEN BAMBOO BUILDING SYSTEM AND DSS

At this stage, there might be a question: What is the relation between the bamboo building system and a DSS in the design process? This relation can be explained as follows:

a. Each sub-system in the bamboo building system should be integrated. Some aspects of integration need decision support during the design process.

b. Decision-making in the design process should be carried out at each design stage.

c. During the integration process of the whole system, the boundary conditions that are present in the integration factor should be considered.

These kind of decisions in the design process can be supported by the DSS. In design process, the decision support is given by the system to provide appropriate alternative solutions.

Figure 5: Three-dimensional Model for the total building domain

(Hill in de Groot 1999)
The types of decision-support in the design process of bamboo building may include: information, evaluation, explanation, computation of technical features, cost calculation of each part or sub system in each proposed alternative solution, and the selection of an example of a previous solution that meets the present criteria.

The required type of DSS depends on the specific parts of the bamboo building system. To yield a complete bamboo building system, the complete DSS may be needed. A bamboo building design decision support system should be considered as an information system for the users. As such, it might be implemented as a guidelines, an audio-visual display or a computer software. It should be noted that in the developing countries, the implementation form of the DSS may not depend on the appropriate type of bamboo building system, but on the ability of the type of users in accessing the information system.

An appropriate DSS can be tested according to the requirements that should meet an information system (Zamanian, 1999), as follows:

a. **Comprehensiveness.** The type and level of complexity of the system depends on what kind of information is needed and how detailed and adequate it is in describing some particular aspects of an artefact at a specific phase.

b. **Non-redundancy.** This should be the rule. However, in some cases, it will be desirable to have some consistent redundancies that are designed and managed to provide information efficiently.

c. **Extensibility.** Information system must be extensible so that necessary modifications and enhancements can be readily implemented.

d. **Classification.** Semantics plays a key role in informations classification, and therefore capturing the correct semantics is extremely important. It is often challenging because the multi-disciplinary and even multi-national nature of the information domain might lead to overlapping its schemata.

e. **Inheritance or reuse of data and behaviour** is provided via the hierarchical class structure of an information system.

f. **Assembly modelling.** Physical objects and processes are not monolithic but are assemblies of various component that can be successively decomposed into more detailed components until no further decomposition is needed or possible.

g. **Multiple referencing.** An assembly-modelling scheme suggests a more structured hierarchical approach. But it is often desirable to aggregate information components in such a way so those components are shared among several assemblies. For example: the connection between beam and column consists of many components which must be considered as part of both beam and column.

h. **Multiple-functional views.** It is common for a component of a constructed facility to perform several functions. For instance: the interior walls of a building are viewed as spatial partitioning elements by architects, but structural designers may assume it as load resisting members, and sometimes as containers for outlets of the air conditioning, water plumbing or electrical utility.
i. **Extensibility to new functional views.** The information model must be extended to accommodate the additional functional views of components and processes required by these disciplines. For example: an environmental view may be developed for monitoring indoor pollution of constructed facilities.

j. **Data accumulation and evolution.** As an information system, it should be developed overtime through various phases of its lifecycle - i.e., design, analysis, fabrication, maintenance, and demolition, various types and forms of data.

k. **Adaptability to codes and standards.** The design and construction of an information system must comply with the applicable local codes and standards. The information model must be adaptable to the codes and standards that guide the creation and use of its content targeted for use in a particular region of the world.

l. **User-defined extensions.** The information model might be unable to address the specific needs of all of its intended users. The protocols for adding user-defined extensions to a model and the mechanism for accessing such information is, therefore, needed.

These requirements will fulfill the completeness and acceptable service levels of DSS and, as result, the DSS should satisfy the users.

**6 DESIGN PROCESS**

The description of the DSS in the previous section had in mind the design process of a bamboo building. The same system can be used for both processes, with adaptations where necessary.

(Bax and Trum 1993)

Figure 6: **The schematic of design process of a stage in a bamboo building**
In this system, Archer (1969) proposes a general approach of design-process which may be appropriate as a model of it, a design process can be described as follows:

a. determining the properties of design stages,
b. determining the objectives of design stages,
c. determining importance rating of objectives,
d. completing performances to fulfil the objectives of design stages, evaluation of performances of design stages.

A designer, at a stage of the design processes, always concerns to three axes (Bax and Trum, 1993): contain axis of the process itself, axis of functional design, and axis of formal design in terms of various levels shown in figure 6.

7 CONCLUSION

I would like to emphasize certain point made earlier, and to elaborate on another points. The DSS as an information system that is suitable for bamboo-building design activities should contains databases, databases management system, user interface, rule base and knowledge management. As an appropriate system, DSS should be applicable to any level of the design process, and be usable by designers at anytime and on any functional designs. In a building system, design processes of the bamboo building can be performed by decomposing the building into sub-systems and can be integrated as a whole bamboo building system under the guidance of the taxonomy of concepts that always exist in the DSS. The decision-support in the building design activities plans major role in the integration process during the design. In other words, completeness and service level of the decision-support system is needed in order to satisfy the users of the DSS.

The design process of a bamboo building can be started with a general view of the building. A designer should always take into account both the lower and the upper level of the building system, the user requirements at each level, and the peripheral properties for each part in the building system. At each stage, a designer may refer back to the previous stage to adjust or modify properties if this is indicated by the following stage (see figure 6).

8 REFERENCES

