SUSTAINING DESIGN DECISION MAKERS IN THE AEC INDUSTRY

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Abstract. Today's typical decision making problem such as strategic planning, portfolio analysis, resource allocation and human resource management involves a variety of tangible and intangible strategic goals, conflicting constraints, dozens or hundreds of alternative initiatives to be pursued, and limited resources. A decision maker cannot meaningfully combine all of this information to make right decisions. To sustain decision makers in the Architecture, Engineering and Construction (AEC) industry, this paper proposes a tool to transfers a complex problem into a concept of hierarchical structure consisting of goal and its criteria and sub-criteria. Irrespective of the applied domains, this tool provides a flexible means for tackling the complex decision making process. It embeds a mathematical model for prioritization and decision making which is based on the Analytical Hierarchy Process (AHP).

1. Introduction

The purpose of information technology is to facilitate the exchange and management of information and has a lot of potentials for the information process component of the AEC industry. Thus supporting IT will undoubtedly have a profound impact on how organizations manage their daily activities. Compared to other traditional industries, the AEC industry has been a little slower in adopting information technology, although this is understandable since the AEC industry tends to prevent risk and prefers to adopt a technology that has been proven.

Design as an intelligent activity is a complex process to perform irrespective of its domain. The complexity stems from the characteristics of this activity itself. There is neither a straightforward procedure to be followed nor goals satisfaction depending on achievement of several interrelated tasks can be solved simultaneously. In this paper, an attempt is made to propose an innovative approach.

To reduce the complexity first we make the problem hierarchy by separating it into several different factors according to its quality and target. Then group the factors into several levels according to their mutual influence and their subordinate relationship in order to form a multi-hierarchy analysis model and finally sum up the system analysis as the determination of the weight which represents the importance of criteria in the lowest level relative to criteria in the highest level.

Sustaining decision makers in the AEC industry with a decision support tool that provides a flexible means for tackling the complex decision process into a simple concept of hierarchy. It is based on the assumption that when faced with a complex decision the natural human reaction is to cluster the decision elements according to their common characteristics. In this hierarchical structure decision makers are able to drill down to their level of expertise, and apply judgments to the criteria deemed important to achieving their goals.

2. Adopting New Technology in the AEC Industry

Although the AEC industry is the largest industry in the world, it doesn't adopt new technologies as the other industries do. Many innovative technology products giving services to the AEC industry go out of business as a result of sluggish adoption rates. While some of them give benefits to that industry in terms of time, cost, quality and safety (Taylor and Bjornsson, 2002).

Some researchers (Koskela and Vrijhoef, 2000; Winch, 1998) believe that innovation gap in the AEC industry results from an ill-conceived theory of construction. Studies in the domain of supply chain management show how production techniques from the manufacturing industry were applicable in the AEC industry (Alarcon, 1993; Melles, 1994). Gann (2000) says that "the ability to manage knowledge and information effectively and efficiently has been central to performance improvement in many industries." He suggests information and communication technologies have formed the underpinning technologies upon which new processes have been built.

Although the facts of sluggishness in adopting innovative technologies are clear, the reasons why the AEC industry adopts new technologies reluctantly are largely ignored by researchers. According to one CIFE, Construction Industry Environmental Forum, seed research investigation (Bjornsson, Sharig and Taylor, 2003) shows the structural and behavioral mechanisms behind the AEC industry innovation gap. That research has initiated steps toward bridging the innovation gap in the AEC industry. They planed to create a proof of concept model of the AEC industry's adoption rate based on the structural and behavioral mechanisms and be able to make predictions for the adoption rates of new technologies. This proposed research effort focused narrowly on the adoption of 2-D, 3-D and 4-D CAD (Computer Aided Drafting) software products.

The proposed sustaining decision tool, irrespective of the applied domains, is a decision support tool providing a flexible mean for tackling the complex decision making process.

3. A Method for Analyzing a Complex Problem

How we can structure a decision making procedure effectively? A well known method called the Analytic Hierarchy Process, AHP (Saaty, 1980) has been widely used for structuring this procedure. The process focuses on making decision on the basis of the criteria of the decision makers. AHP defines a process for breaking down a problem and managing the complexity of the problem by organizing its elements into a hierarchy or structure. This hierarchy contains a goal at the top level of the hierarchy, criteria in the second level and alternatives of choice at the next level.

Generally, AHP is one of methods known as multi-criteria decision making. The mathematics of the method is left to the reader to explore it. The methods help to select from a number of alternatives evaluated with respect to several criteria. It carries out pair-wise comparison judgments to develop overall priorities for ranking the alternatives. AHP consists of three steps: decomposition of the problem, establishing priorities and synthesizing results.

The first step focuses on decomposing the given problem and structuring it into a hierarchy form. In this step the problem is transferred into a hierarchical structure. It views the given problem in a structure consists of the goal and its criteria, sub-criteria and alternatives. In the next step the priorities of the criteria and sub-criteria are derived using pair-wise comparison values. These values are very crucial and should be gathered by consulting with experts and decision makers in the field. The second step is a process of prioritization which involves eliciting judgments about the importance of one criterion to other criteria with respect to each criterion in one high level in the hierarchy.

The third step involves with synthesizing priorities and results. Synthesis is the process of weighting and combining priorities after judgment are made to yield the final result. Finally, the process sums up to determine the weight which represents the importance of the alternatives or selection choices relative to the overall goal.

4. Sustaining AEC Industry Decision Makers

To sustain decision makers not only in AEC industry but irrespective of the applied domain we have developed a tool to support the process of decision making. See (Chitchian and Bekkering 2005) for details and features of this tool. In another paper from the same authors (2006) was explained how this tool helps urban designers to make decision in their urban environment design tasks. As explained before AHP is a method known as multi-criteria decision making. The method facilitates making decisions on the basis of criteria. Embedding this method in our developed tool makes it as a general decision making tool for all decision makers in many domains.

To represent the capability of the proposed tool in AEC industry we resort to an example in the project management control. Project management is a discipline that uses standardized methodologies to deliver complex, limited duration projects considering some aspects such as time, cost and quality constraints. The project management institute as an international professional organization for project managers sets standards in this field. The standards are documented in a publication titled PMBOK, A Guide to the Project Management Book of Knowledge. These standards should be considered by project managers and experts as main criteria while they analyze projects. We stick to these standards while making decisions about projects using the proposed tool.

4.1 PROBLEM DEFINIATION

Each year in organizations involved in construction projects management decisions are made to allocate resources such as time, man power and money to various projects. With respect to the limited amount of available resources managers must decide to fund some of the current projects. There exist different ways to resource project management on a project. Here we consider three ways to do that. They are: *full project management*, *streamlined project management*, and *no formal project management*. In this section we explore an example elaborated by Thorn and Dixon (2002). Also assume there are three projects, called *A*, *B* and *C*, each with certain constraints.

Six criteria are considered for comparison. These criteria are in accordance with given standards in PMBOK. They are:

- **Priority,** it shows how important is a project and what is its impact in managerial work. Project with higher priority needs more management effort in an organization.
- **Duration,** this determines the time limit of a project. So longer projects need more planning and monitoring tasks.
- **Level of complexity,** this criterion shows how complex are projects. The more complex a project is the more integration management is needed. The level of complexity is identified by three sub-criteria. They are: system, business and technical. Each sub-criterion indicates some aspects of projects depending on their complexity.
- **Risk,** this criterion indicates impacts of a project with respects to some point of views. The project risk can be divided into few categories such as political, social and success. Here we consider only political and success risk.
- **Resources,** they determine different assets of an organization projects consume. Depending on a project certain resources are needed. Some of them are: staffs, contractors, sponsors and executives. Here we assume only two resources for simplicity.
- **Financial,** this criterion is defined by two sub-criteria, total cost and the return of investment. The first one shows overall expenditure and the second sub-criterion shows how fast and how much profits or saving will be compensated.

What is the best way for resourcing project management of each project? We want to find out how to manage those three projects, *A*, *B* and *C*, considering the mentioned criteria. In other words three project management ways will be tested against every project. To answer the question we should analyze the problem and find answers about how to complete projects on budget and on time, control the original scope and quality of projects, employ risk management and manage resources.

4.2 DEPLOYING THE PROPOSED DECISION SUPPORT TOOL

This section explains how to use the proposed decision support tool. The process of making decision using this tool involves three steps. In the first step the problem hierarchy is constructed according to the given information in the previous section. The hierarchy will be created with respect to criteria and sub-criteria relevant to the given problem. In the next step all pair-wise comparison for all criteria and sub-criteria in the model for each of the three projects must be given. Once all comparison values are entered, in the last step the AHP module of the tool will be activated to synthesize the results.

Working with this tool is straight forward readers should refer to other papers from authors given in the references section. The user interface of the tool is depicted in figure 1. Using utilities of the tool, shown in this figure, you can create the problem hierarchy in the left panel of the user interface.

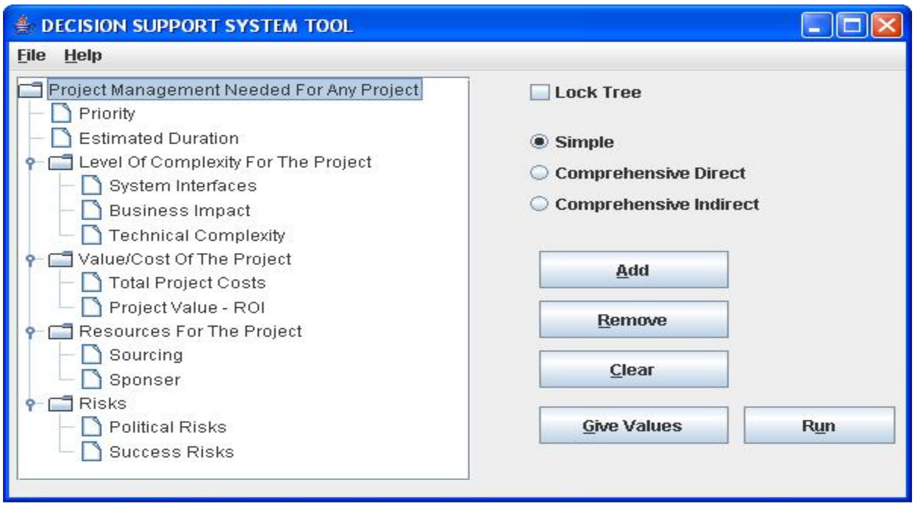

Figure 1. The User Interface of the Decision Support Tool.

After creating the problem hierarchy, all pair-wise comparison values for all criteria and sub-criteria must be given. Clicking the *Give Values* button in the user interface a menu pops up where you can enter all required values. A pair-wise comparison value between two criteria shows how important is one of them compared with the other one. These pair-wise numerical comparative judgments between criteria must be given by an expert in that domain. The numerical values are usually between 0 and 1 which represents a 9-points scale. The minimum pair-wise value of two objects, 0.1, shows these two objects are *equally importance* with respect to a certain aspect given by an expert. Also the maximum pair-wise value, 0.9, says that one of these objects is *extremely more importance* with respect to the same considered aspect. The other values between these two numbers, 0.1 and 0.9, indicate the relative importance of these two objects with respect to that aspect between these two extremis, *equally importance* and *extremely more importance*. Note that pair-wise comparison values for all criteria and sub-criteria of three alternative solutions, *full project management*, *streamlined project management*, and *no formal project management* for each of three projects must be given separately.

The preference for each alternative project management with respect to each criterion must be compared. Assume project *A* has higher priority than the other two projects, *B* and *C*. Therefore *full project management* is more preferred than *streamlined project management* for this project. Figure 2 shows the menu where the user enters pair-wise comparison values for priority criterion of project *A*. Only in the lower part of the matrix values are entered. Since project *A* is high priority, also considering the aforementioned 9-points scale the user must give right pair-wise values to reflect the preference for project management with respect to priority criterion. The given values are shown in this figure.

In the same way, pair-wise comparisons values must be entered for other criteria and sub-criteria, as shown in figure 1, of the three projects, *A*, *B*, and *C*. The other menus for entering these pair-wise values are not shown here, the user follows the procedure of entering other pair-wise values as explained before.

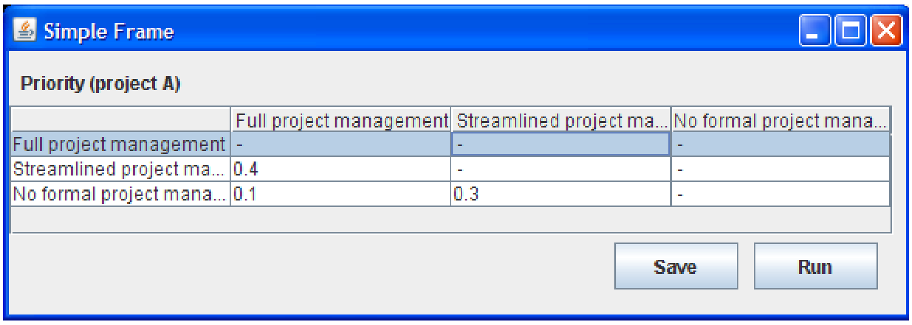

Figure 2. The menu for entering pair-wise comparison values.

After giving all required pair-wise values the AHP module must be activated in order to prioritize the ranking of each decision alternative and synthesize the results. Clicking the *Run* button this module will be executed to do this. The results can be shown numerically as well graphically using provided buttons in the menus of the tool. First we derive priorities for each sub-criterion with respect to its criterion. Then priorities are derived for any criteria with respect to the goal. The synthesized results of all pair-wise comparison are shown in figure 3. The upper part of the figure shows the relative importance of the criteria of the project *A* with respect to the goal. Also the lower part illustrates the relative preference for the three alternative ways of projects management for this project.

4.3 ANALYZING THE RESULTS

As shown in figure 3 for project *A risks* and *level of complexity* criteria have the highest priority also *resources* and *estimated duration* having the least importance. Also derived result says that the preferable alternative of project management for project *A* is *the full project management*. Definitely the *no formal project management* alternative isn't a choice for this project.

To validate the derived results of the tool we compare them with the intuitive decision that experts in this field will make. This comparison helps to find out mistakes that we might have during the evaluation step. If the intuitive results mach with the recommended results of the tool it means that the judgment made by the tool are rational and acceptable. In case the comparison shows some discrepancies between results we should investigate if the constituent criteria and sub-criteria of the model are realistic and also the given relative importance values among them are in accordance with experts' intuition.

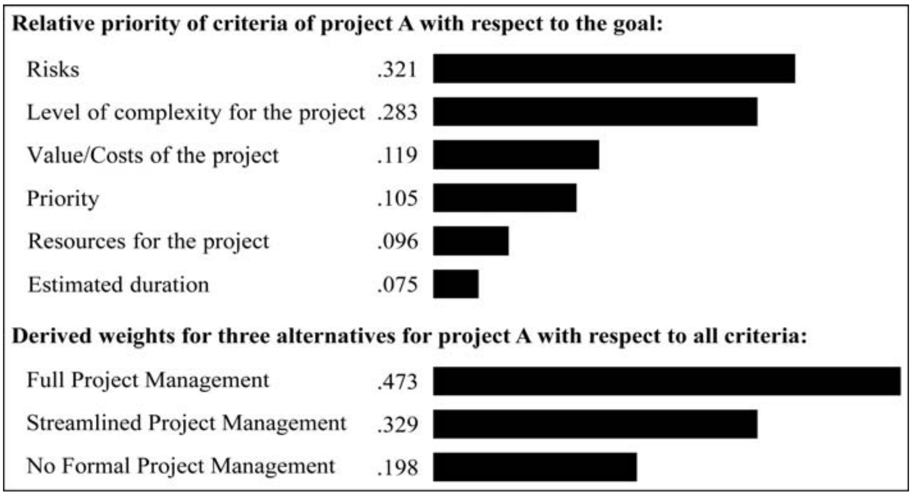

Figure 3. Derived priorities of criteria and relative preference of three alternatives.

Sensitive analysis is a means for evaluating the results. It helps us to realize the effect of criteria on the selection of the alternatives. It shows how important each of the criteria is in making final decision. This analysis also indicates how the preference of alternatives varies by changing the priority of criteria. In other words it shows how sensitive criteria are with respect to certain derived results. So if the sensitive analysis doesn't make sense with our intuition then further evaluation of the model is required.

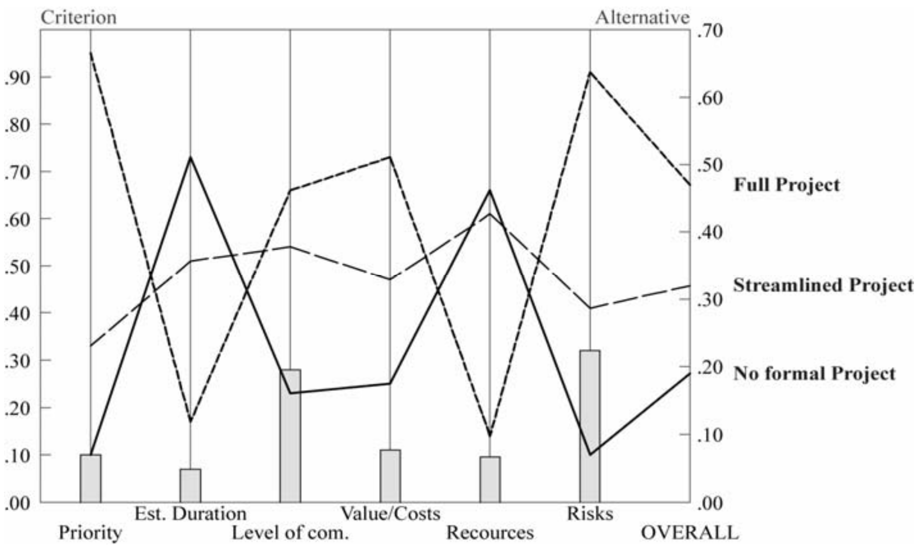

Figure 4. The sensitive analysis of project A.

Figure 4 shows the sensitive analysis of the project *A* with respect to the given criteria. According to *priority*, *level of complexity*, *value/cost* and *risks* criteria the preferred alternative for project *A* is the *full project management*. Because these criteria have higher priorities compared with those of other two alternatives, *streamlined project management*, and *no formal project management*.

5. Conclusions

In this paper we have explained how the three projects have been evaluated using the proposed decision making tool. As expected, the results have proven the hypotheses or expectations we put forward. The sensitive analysis doesn't show inconsistencies in the derived results. Based upon our expectation and information gathered from project management literatures for the evaluated projects, the proposed tool advises the right level of project management efforts.

This tool guides decision makers in structuring a decision into smaller parts, proceeding from the goal to criteria to sub-criteria and further to the alternative courses of action. The proposed system is helpful for decision makers in many decision making problems irrespective of their domains which are generally multidimensional and too complex to be solved with conventional means.

Since we are still experimenting with this proposed tool and trying to make it a more practical tool, further improvements are needed. In doing so, we should seek feedback from experts in project management while creating the problem hierarchy to define goal, criteria, sub-criteria and decision alternatives. Augmenting its capability and enhancing the existing features, we do believe the proposed tool makes a useful tool for decision making.

References

Alarcon, L.: 1993, Modeling waste and Performance in Construction, *Proceedings - 1st Workshop on Lean Construction*.

Chitchian, D. and Bekkering H. C.: 2005, A Decision Support Tool for Decision Makers, *Proceedings of the 23rd Conference on Education in Computer Aided Architectural Design in Europe, ECAADE 23*, Portugal, PP715-721.

Chitchian, D. and Bekkering H. C.: 2006, Information Processing System to Analyze An Urban Environment, *Proceedings of the 3rd International Conference on Cybernetics and Information Technologies, Systems and Applications, CITSA 2006*, USA, PP196-201.

Gann, D.: 2000, *Building Innovation: Complex Constructs in a Changing World*, Thomas Telford Publishing.

Koskela, J. and Vijheof, B.: 2000, The Prevalent Theory of Construction is a Hindrance for Innovation, *Proceedings of the Eighth Annual Conference of the International Group for Lean Construction IGLC-8*, PP100-108.

Melles, B.: 1994, What we Mean by Lean Production in Construction?, *Proceedings – 2nd Workshop on Lean Construction*.

Saaty, T. L.: 1980, The Analytic Hierarchy Process, New York, McGraw Hill.

Saaty, T. L. and Niemira M. P.: 2006, A Framework for Making a Better Decision, *Research Review*, **13**(1), 1-4.

Taylor, J. and Bjornsson, H.: 2002, Identification and Classification of Value-drivers for a New Homebuilding Supply Chain, *Proceedings of the Tenth Annual Conference of the International Group for Lean Construction IGLC-7*, PP1-12.

Thorn, J. and Dixon, C.: 2002, Choosing Just the Right Level of Project Management for Small Projects, George Washington University.

Winch, G.: 1998, Zephyrs of Creative Destruction: Understanding the Management of Innovation in Construction, *Building Research and Information*, PP268-279.