Implementation Issues of a Design Review System using Virtual Environment

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Abstract

In any construction project, a design review process is used by the project team as a means to detect and identify discrepancies, errors and inconsistencies in designs. We established that the current approaches i.e. (1) paper-based checklist system, (2) web-assisted checklist system and (3) using PMUs are based heavily on 2D paper based drawings can be improved and enhanced by using VE-based design review system. Using this system designs can be better coordinated, visualized and understood, and errors can be reduced effectively. However, various development issues need to be considered before a VE based design review system can be fully implemented and usable. The main issues include checklists formation, user participation, software development, information management and leadership are discussed in this paper.

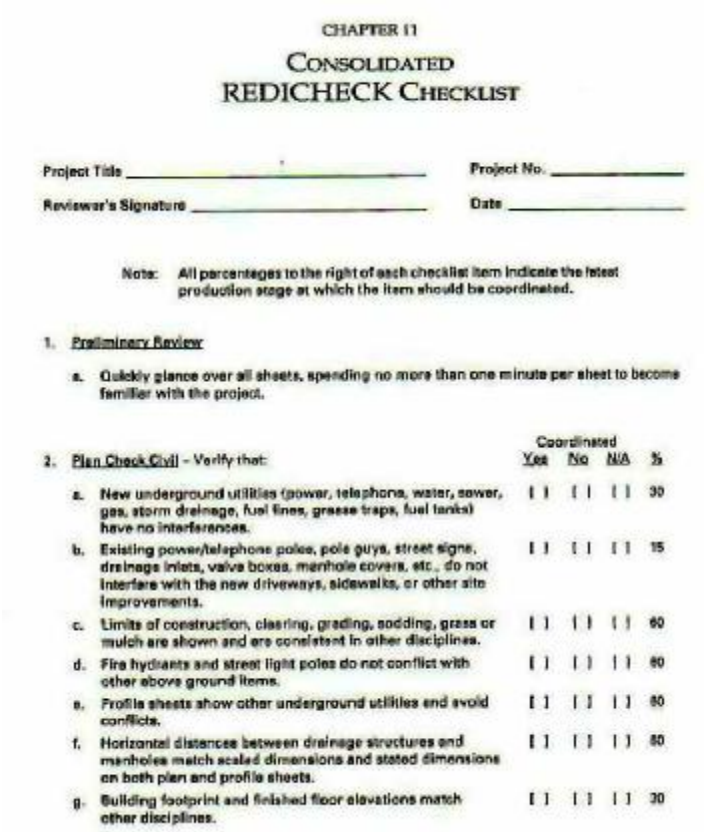
1.0 INTRODUCTION

In any construction project, a design review process is used by the project team as a mean to detect and identify discrepancies, errors and inconsistencies in designs. This process is necessary because design documents for a project are prepared by various design professionals such as the architect, structural engineer, mechanical engineer, electrical engineer etc. Redesigns are common after each design review session and it is made meticulously slow because drawings are produced in paper-based form (either hand-drawn or using CAD software) that are typically viewed in 2-dimension (2D). Throughout the design phase, the 2D drawings are passed from the designers to the reviewers and from one design discipline to the other, and vice versa for critique and redesign until satisfactory designs are accomplished and ready for construction. The process is tedious, time-intensive and there is no effective design review system that can be used to automate the process. Due to these constraints, design review sessions are usually held only a few times during the design phase resulting in the unresolved or undetected errors to occur in the actual construction.

This paper is a work in progress based on a current ongoing research at Virginia Tech to utilize VE technologies to support the design review process. The research main objective is to develop a framework for a generic design review model that utilizes VE. We believe a VE based design review system can produce the maximum benefit of early coordination and collaboration among designers, contractor and owner. This paper first discusses the current design review process generally employed by design firms and/or consultants. The paper then investigates the issues needed to be considered in the implementation of a VE based design review system.

2.0 CURRENT DESIGN REVIEW PROCESS

Despite the benefits of design review in reducing number of conflicts cost, the process is somewhat taken lightly. This is due to the review process is usually resource and time intensive, and often resulted to the review being performed at an inappropriate level of effort. According to Nigro (1992), an average project contains five coordination errors per contract drawing and a project of 500 drawings will typically contain 2,500 coordination errors. Most design review is performed by comparing or combining 2D drawings in meetings. Errors or elements that cross or overlap are detected through manual inspection by overlaying the drawings on the 'Light Table', and evaluated for conflicts. If a conflict exists, actions such as corrections and redesigns would take place to avoid further errors, unwanted change orders and unwanted increase in total project costs. Design review is either performed in-house by the designer's firm or by a consultant firm. Through our investigation, we observed there are two main approaches in performing design review; i.e. firstly using the pen and paper approach and secondly electronic reviews through the use of a web-based system. A third approach is the use of a life-sized physical mockups or PMUs.



CHAPTER 11

CONSOLIDATED
REDICHECK CHECKLIST

Project Title _____ Project No. _____

Reviewer's Signature _____ Date _____

Note: All percentages to the right of each checklist item indicate the latest production stage at which the item should be coordinated.

1. Preliminary Review

   a. Quickly glance over all sheets, spending no more than one minute per sheet to become familiar with the project.

2. Plan Check Civil – Verify that:	Coordinated Yes	No	N/A	%
a. New underground utilities (power, telephone, water, sewer, gas, storm drainage, fuel lines, grease traps, fuel tanks) have no interferences.	[ ]	[ ]	[ ]	30
b. Existing power/telephone poles, pole guys, street signs, drainage inlets, valve boxes, manhole covers, etc., do not interfere with the new driveways, sidewalks, or other site improvements.	[ ]	[ ]	[ ]	15
c. Limits of construction, clearing, grading, sodding, grass or mulch are shown and are consistent in other disciplines.	[ ]	[ ]	[ ]	60
d. Fire hydrants and street light poles do not conflict with other above ground items.	[ ]	[ ]	[ ]	60
e. Profile sheets show other underground utilities and avoid conflicts.	[ ]	[ ]	[ ]	60
f. Horizontal distances between drainage structures and manholes match scaled dimensions and stated dimensions on both plan and profile sheets.	[ ]	[ ]	[ ]	60
g. Building footprint and finished floor elevations match other disciplines.	[ ]	[ ]	[ ]	30

Figure 1: A sample of REDICHECK checklist

REDICHECK (http://www.redicheck.com) is a consultant firm that uses the first approach. They specialize in quality assurance reviews and training. The firm uses the REDICHECK review system (which is defined by its originator Mr. William T. Nigro) as a construction document system specifically designed to address points of interface,

allowing production personnel or a quality assurance reviewer to establish coordination discrepancies between disciplines. The REDICHECK system uses an interdisciplinary coordination paper-based checklist (Figure 1) and overlay checking process. The interdisciplinary checklist is based on the sequence of construction i.e. civil checklist, structural checklist, architectural checklist, mechanical/plumbing checklist, electrical checklist, kitchen/dietary interdisciplinary checklist, specification checklist and finally consolidated REDICHECK checklist. All the REDICHECK checklist items are coordinated no later than 60% completion of the construction document production stage. As each item is checked, problem or discrepancies with other disciplines is communicated. The disciplines where the solutions may affect are also notified.

An example of web-based form of design review system is the Design Review and Checking system or DrChecks (http://www.buildersnet.org/drchecks/), developed and used by the U.S. Army Corps of Engineers. The DrChecks system links designers, reviewers, project managers and other interested parties via the Internet to track and submit reviews and comments of construction plans and specifications (enr.construction.com, 2002). The users are able to sort comments by date, discipline, reviewers and other categories. Typically, a project manager creates review phases for each project and reviewers submit comments during each phase and designers can then evaluate and respond to each comment. All communication between parties is logged and stored on a centralize database system. Drawings and other types of important files can be attached to the postings. Integrated within DrChecks system is the Corporate Lessons Learned (CLL) system that allows the team members to identify their customer and the location of specific criteria, lessons learned, success stories and good work practices.

Figure 2: An example of a physical mock-up used for a design review session (Courtesy of Pulte Homes, Inc.)

A third approach of design review involves the use of a life sized physical mockups (PMU) of a building or facility to be built (Figure 2). This method is used by large and resourceful companies such as our industrial partner, Pulte Homes, Inc. During their design review session, the project participants inspect and discuss various aspects and components of the design by physically walking through it. The outcome of every discussion is written down, or drawn directly onto the 2D drawing, marking design errors, or suggesting improvements to the design. Decision is then made whether the model must be reworked, is ready for construction or in need of enhancement. If enhancements are necessary, modified information are passed to the designer for the incorporation of the changes onto the 2D drawings.

From our investigation, the design review process still lacks automation. The process is slow and relies on CAD drawings that are typically viewed 2-dimentionally (Shiratuddin & Thabet, 2003). These 2D drawings are passed from among designers for critique and redesign until satisfactory designs are accomplished and ready for construction. It is still resource and time intensive and errors remain undetected until the actual construction on site. An improved method of performing design review is therefore needed; and we are proposing the use of VE.

3.0 PROPOSED FRAMEWORK FOR A VE BASED DESIGN REVIEW SYSTEM – DESIGN ISSUES

Our proposed design review system uses VE with the addition of real-time characteristics (Shiratuddin & Thabet, 2003). 3D representation of the virtual facility to be built can be updated in real-time reflecting user changes and modifications. Brooks (1999) discusses the technology progress of the use of VE for product design and design review. VE is successfully used in other industries except construction. We see an avenue where VE can be used as successful in construction industry, especially during design review. However in order for a design review process using VE for construction to materialized, the following issues in designing the system have to be assessed and resolved.

Figure 3 shows some of the major issues that need to be considered in the development of a usable VE based design review system. The issues can be classified into 5 areas and they are: (1) design review processes issues (2) end-user related issues (3) hardware and software issues (5) information management issues and (4) collaboration and participation issues. Each of these main issues is further classified into smaller issues. The sections below describe some of the main issues shown in Figure 3.

3.1 Design Review Processes –Design Review Checklist Issue

As discussed earlier, design review checklists breakdown mainly done by discipline (e.g. REDICHECK, or by the CSI Master Format e.g. DrCheck). Our research will look into the viability in creating a checklist that is based on a new format such assemblies and components. Further investigations will identify the common checklists items that are present in the systems and techniques used by design and/or consultant firms. Newer necessary attributes will be investigated and incorporated into the new system.

3.2 Participation Issues - The Users

Users of the proposed design review system have to be determined so that the functionality of the system could be met. Users could be the owner, designers, engineers, managers or other designated personnel. It should also be established whether a participant should participate in the design review session from the very beginning to the end or be involved in partial stages of the process. Therefore user's level of accessibility to the system and the ability to make changes to the 3D model should be decided. The design review system will have to be designed in such a way that users can participate in

the review process with the options of conducting the design review session individually or collaboratively; locally or remotely. Users will also be able to modify the 3D model in the VE in real-time throughout the design review period. Users will be able to assemble and visualize the configurations of the end result, identify conflicts or compare and rate different designs.

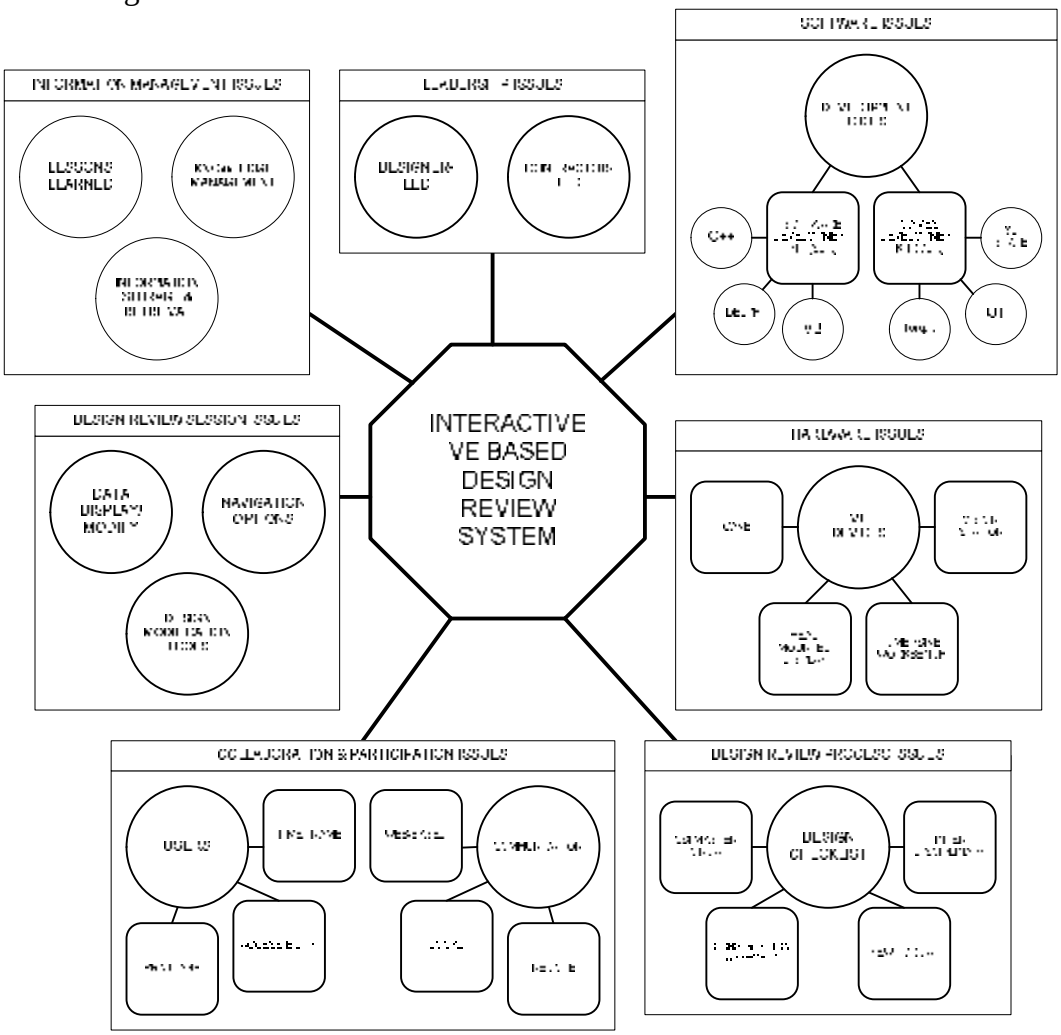


Figure 3: Issues needed to support implementation of a VE based design review system

3.3 Software Development Issues - The Development Tool

To develop the design review system, an economical and extensible development tool will be selected. Cost of implementation, the ease of implementation, future extensibility, maintainability and the user-friendliness of the system should be the important factors to be considered. To date, we propose the use affordable 3D Game Development Kit (GDK). Our previous studies (Shiratuddin & Thabet, 2002) have established the use of Unreal Tournament (UT) GDK that came off the shelf with the game, as a viable solution to providing a better and more realistic real-time VR walkthrough environment. Our recent research (Shiratuddin & Thabet, 2003) concluded that UT may not be extensible

enough in the long run for the proposed design review system without the entire source code made available. We are currently investigating and using a different 3D Game Engine known as 3DState (http://www.3DState.com).

3.4 Information Management Issue - Knowledge Management

A method has to be created in order to store, organize and represent the design expert's knowledge and experience. Important knowledge and experience needed to be captured and abstracted from the design review sessions so that a lesson learned database can subsequently be created. Options include the designers to document and possibly record their steps and actions during the process. The knowledge and experience can be pre-defined into building blocks of design. The building blocks may be in the form of design firm's strategies, designers' problem-solving skills, etc. These building blocks can be re-used to enable designers and users of the system to explore the structures of new design problems and their solutions. A few databases may have to be created to store (1) default-building components, multidisciplinary data for the (2) architectural, (3) structural, (4) mechanical, and (5) electrical designs, (6) short-term and long-term design changes, i.e., models of proposed changes and applied changes, respectively, and (7) lessons learned.

3.5 Leadership Issue

It has to be decided on who should head and be responsible for the design review effort. Either a designer-led or a contractor-led project, a project manager seemed to be an ideal choice. The project manager must have the highest level of control over available design review resources and procedures, recruiting other members, leading team meetings, managing and implementing the design review improvements. The project manager should also be able to assign roles of team members based on individual areas of expertise and expected contribution. Additionally, the project manager should be able to ensure availability of team members so their expertise can be sought when needed. A formal agreement should also be ensured on the procedure and objectives of the design review.

3.6 Design Review Session Issues

Since the review session will occur in real-time in a VE, issues outlined in Figure 3 i.e. data display methods, navigation options and design modification tasks and features have to well thought and researched. In our investigation, we found every project is unique and deployment of design review tasks can varies from one to another. However, there existed common similarities of review tasks. These similarities will be studied to see whether they are suitable to be used in a VE. The way data will be displayed in VE will also have a significant impact on the review process. We are currently investigating the types of data that will be displayed and how they will be presented to the users.

4.0 SYSTEM DEVELOPMENT

Given the issues diagram shown in Figure 3, development for the VE based design review system is currently underway (Shiratuddin & Thabet, 2003). Three main system modules are proposed: (1) Design Modification module; (2) Information Manipulation module and (3) Collaboration module (see Figure 4).

The 3DState GDK is selected to develop the prototype VE based design review system. The GDK is developed by 3DState and can be downloaded at http://www.3dstate.com. The 3DState GDK comprises of more than 500 ready made 3D APIs that can be used to develop 3D related applications. Since 3DState can be used with standard programming languages such as C++, Visual Basic and Delphi, the extensibility of the proposed system is more viable. Currently, we are focusing on developing the object manipulation (see Figure 4) feature which is a sub module of the design modification module. 3DState APIs and Visual Basic is used to develop it (see Figure 5). Some of the object manipulation features will include the ability for users to move components in the VE from one location to another, moving components in a specified axis and also to rotate, delete and loading new components.

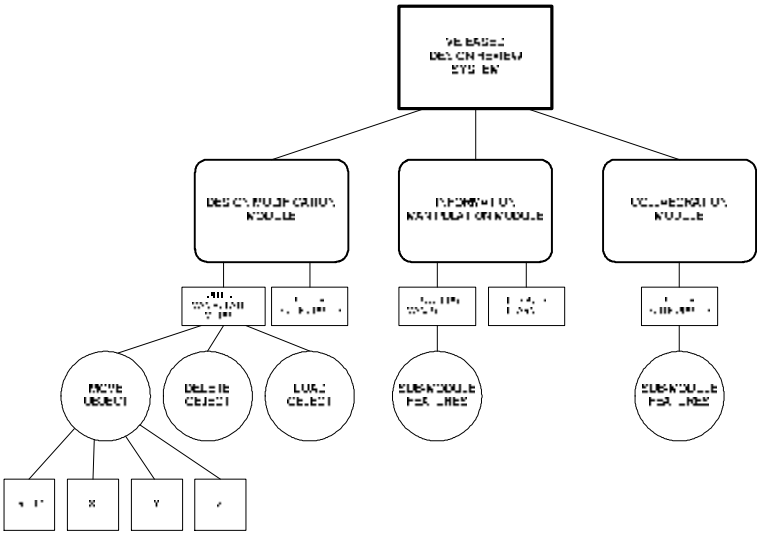


Figure 4: The modules of the proposed VE based design review system

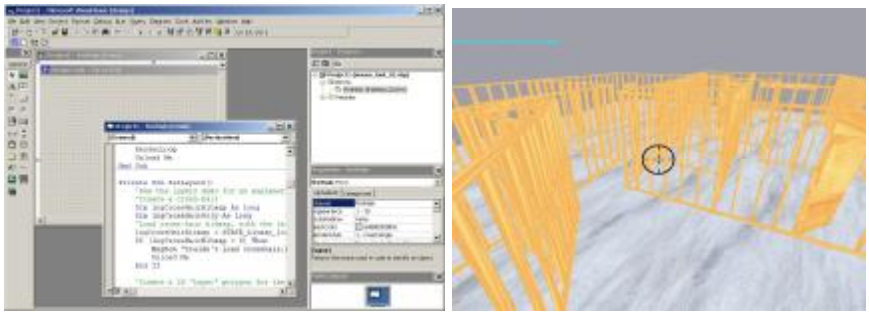


Figure 5: 3DState & Visual Basic development environment and prototype screen capture

5.0 CONCLUSION

In this paper, we propose a VE approach to support the design review process. A real-time interactive 3D VE implementation will offer the project team many benefits and will allow the project team the ability of making on the fly changes and modification of the 3D model hence minimizing the lengthy process of design and redesign. Other benefits of a VE-based approach will include making design conflicts more visible to designers and planners, errors can be corrected at an early stage, hence unwanted change orders and unwanted increase in total project costs can be minimized or even avoided. The proper design of a VE-based design review system will need to consider the issues described in this paper. As the research moves forward, more issues will be added to ensure the framework for the design review system is robust.

6.0 REFERENCES

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