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Quality People. Quality Projects.

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Abstract:

The primary objective of this paper is to introduce the use and importance of virtual construction tools for pre-project planning. Virtual design and construction has shed a new light on pre-project planning which has tended to be overlooked. At the onset of the essay, a brief background of virtual design and construction is presented. Immediately following, various virtual construction tools are listed explaining their benefits, how they enhance collaboration, and the specific pre-project planning tasks that each tool can be utilized. The essay ends with a discussion on how my educational experience has prepared me to use virtual construction.

Background of Virtual Design Construction:

Many significant developments in Virtual Design and Construction (VDC) have transcended the operations of architectural, engineering, and construction industries. VDC has shown to improve coordination and the exchange of information by allowing the users to more accurately visualize, analyze, and evaluate project performance. This increase of efficiency through collaboration has shown advantages of eliminating unnecessary costs, reducing project construction time, detecting errors before they become costly, and improving the alignment of team members. Essentially, VDC has allowed the construction industry to make informed project decisions and investments before any workers even enter the jobsite (Building Explorer, Inc., 2009). This effectiveness and efficiency in regards to minimizing waste and limiting extra costs has not always been a foreseen reality in construction. It can be deduced by the information presented in Figure 1 that since approximately 1977 many non-farm industries have seen remarkable improvements to productivity in contrast to the construction industry. Since that same time productivity in the construction industry has remained relatively stagnant. New improvements to VDC can alter this trend to maximize productivity and possibly even surpass the productivity of many other industries. In recent case studies by the US Government, the lack of the interoperability of tools between project participants in the construction delivery process has amounted to

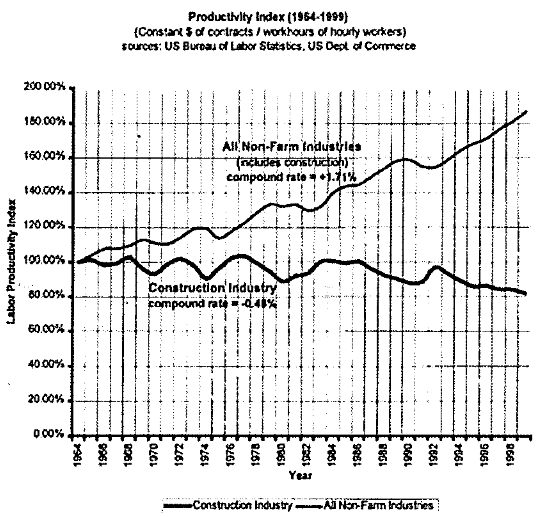

Figure 1 – Productivity Index

$15.8 billion each year of industry wastes (Gallaher et al, 2004). Ultimately, a major focus of the construction industry must center on discovering a better approach of using VDC to create a more integrated system to construction (Khanzode, 2006).

Benefits and Collaboration Examples of VDC Tools for Pre-Project Planning Tasks:

A multitude of tools have been created and expanded upon under the practice of VDC. These tools include laser scanning, 3D model creation and collision coordination, daylight and air-flow modeling, animation of wind loads, 4D modeling, site staging and logistics planning, and 5D modeling. All of these tools have been used on projects to identify time-space constraints through visualization, supply realistic representations of the project to improve communication, create models to aid coordination of a variety of disciplines, evaluate project sequences before the construction phase of a project, and to provide constructability analysis. The dynamic nature of VDC enables the construction industry in due course to see the unforeseen (Khanzode, 2006).

Laser Scanning:

Laser scanning uses laser light to capture spatial data by utilizing millions of points each with a distinct latitude, longitude, and elevation (XYZ) coordination. A complete model is formed after multiple scans are performed in the given area to gather every side of the project. Once this is accomplished, all the data sets can be compiled to create a 3D model of the scanned area. Applications of this tool include and are not limited to determining volumes of stockpiled soil and aggregate, creating topographical surveys, scanning pre-existing buildings to aid in the pre-construction phase of building renovations, and the retrofitting and expansion of healthcare facilities. The level of detail of laser scanning far surpasses the use of GPS equipment. For example, the majority of land surveys utilizing GPS typically only supply a single point with an XYZ coordinate 10-50 feet apart. Laser scanning provides coordinates of less than an inch apart creating a more accurate and applicable model. Cost containment/budgeting and improved scheduling are other substantial benefits of laser scanning. Manual measurement processes have shown to be much less cost effective compared to laser scanning. Not only are manual measurements error prone which can ultimately cause the need of extensive rework, they demand a greater length of time to complete (Spooner & Associates). Laser scanning also reduces the need of field trips due to the accuracy and visibility of the generated 3D model. The review process of the project becomes much simpler when accurate data and information is available essentially anywhere at any time. When fewer RFI's are needed, it can dramatically reduce project delays which add up to huge time and cost savings (Darling Geomatics).

3D Architectural Modeling:

3D modeling is extremely beneficial early in the project definition phase. Through 3D modeling, the design team can communicate exactly what they expect in the look and feel of the project between themselves and also the stakeholders. The 3D model creates an easy and efficient method of communication to create a shared vision. 3D models can be generated to establish the design for site improvements, the exterior of a building (Figure 2), and also all interior finishes. By incorporating the 2D data, materials, and drawings to create a 3D architectural model, the construction and design team can have better insight to see if

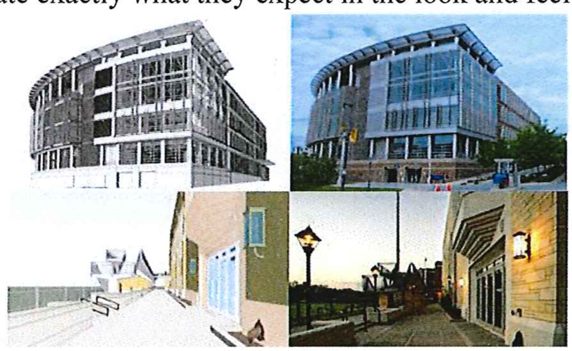

Figure 2 – 3D Architectural Modeling

their plans reflect the correct anticipated look of the project and if the drawing process included any errors. 2D plans can only depict a limited amount of details. 3D renderings give additional understanding of surface patterns both inside and outside of the building. Another benefit of 3D modeling in pre-construction efforts is to efficiently market and advertise the product. Architectural walkthroughs and virtual tours can be generated to enhance communication in owner meetings to ensure the product they are receiving mirrors their exact wants and needs (Architectural Illustration).

Virtual Mock-Ups:

Virtual mock-ups utilize 3D modeling to verify design and enable a deeper comprehension of construction expectations long before groundbreaking occurs. Virtual mock-ups encompass a variety of building components including enclosure systems

Figure 3 – Virtual Mock-Ups

and interior finishes. Figure 3 depicts an example of a virtual enclosure system mockup formulated by Mortenson Construction. The virtual model creates a better understanding of the end product and the assembly sequence. By identifying the relationship of how objects are constructed together, the construction process can be streamlined in the field. Also, if any errors are shown in the mockup, the amount of RFI's will be reduced in the future and issues can be identified before they negatively impact the budget and schedule (Filkins, 2012).

3D Collision Coordination:

Through the methods of 3D collision detection, the construction team is able to incorporate all of the project's major systems, mechanical, electrical, plumbing, fire protection, etc., into one model to pinpoint any design conflicts and constructability concerns. Manual checking of 2D drawings can be very error prone and many clashes in the project's systems can easily go unnoticed.

Figure 4 – 3D Collision Coordination using BIM

Recognizing clashes before construction begins allows the construction team to fix the issue ahead of time to ensure smooth installation. Early detection avoids unnecessary rework, fabrication, and wasted time (Exponent, Inc.). 3D collision detection has become a reality with the issuance of Building Information Modeling (BIM) software. Figure 4 represents a BIM model to the left and the actual construction to the right. The level of detail of the BIM model exactly reflects the true construction of the building. BIM technology has ultimately reduced risk of the construction phase (Exponent, Inc.).

Daylight Modeling, Airflow Modeling, and Animating Wind Loads:

Daylight modeling, airflow modeling, and animating wind loads are all examples of 3D modeling to assist in the design phase of a building. The importance of daylight is often overlooked in construction. The correct application of daylight can essentially make a building come to life; and if not properly implemented in design, the use of daylight can negatively affect the building and its occupants. The use of daylight ultimately affects the mood of the space, and especially in office settings, daylight is necessary to maintain comfort, productivity, and performance. Specific examples of daylight modeling include climate-based, glare recognition (Figure 5), and false color modeling. With these models, the construction and design team can coordinate to discover glare, overly bright areas, dark spaces, and poorly balanced light levels. Airflow modeling is similar to daylight modeling in that they both ensure occupant comfort (Kalwall).

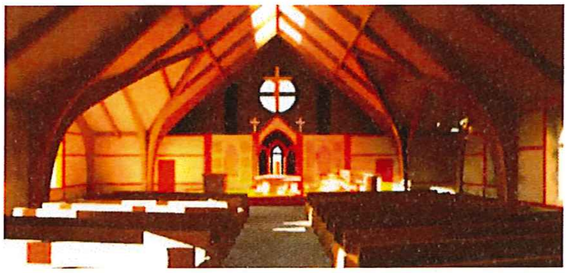

Figure 5 – Glare Recognition Modeling

Airflow modeling allows the project team to visualize in three dimensions how a building's HVAC system will perform under a range of conditions. Specific areas of airflow recognition include airflow velocities, air intake, exhaust placement, and air movement. Large spaces, for example auditoriums, require a greater amount of collaboration and planning to guarantee a sufficient air movement (CHMHILL). Additionally, when building projects are located in high wind load areas, air flow analysis is crucial before any construction efforts commence. Simulation tools can be used to recreate various wind loads to test the structure of buildings and even cranes. Cranes are among the most expensive types of equipment and entail a multitude of safety requirements, so it is crucial to select a crane that meets environmental conditions. In regards to buildings, BIM technology enables users to analyze external airflow to minimize unwanted "canyoning" effects and overall building performance (Autodesk, Inc.).

4D Modeling:

Another critical VDC tool is 4D modeling. Several common 4D software and service providers include Navisworks, Intergraph, Bentley, and Common Point. 4D modeling incorporates both 3D modeling and a project's critical path method (CPM) schedule in order to generate a virtual construction simulation. With 4D modeling the project scope can be more efficiently communicated to the entire project team and the overall project schedule can be assessed and validated before the work begins. By optimizing project phasing through the incorporation of the time element to 3D modeling, the transition from the design phase to the construction phase becomes less daunting of a task. The entire project team is able to be on the same page since 4D models facilitate communication and allow face-to-face meetings to be more productive than simply reviewing a CPM schedule. 4D models have a greater ability to manifest major project risks that in due course would be overlooked. When subcontractors know exactly what is expected of them in terms of when to work and how everything is to be constructed, the likelihood of change orders will be reduced dramatically and fewer requests for RFIs will be needed which ultimately increases productivity and cost predictability (Fischer). An example of sequencing with 4D modeling is shown in Figure 6. In this figure, the sequencing for mechanical, plumbing, and electrical systems along with the installation of drywall is depicted starting from the top left of the figure and moving clockwise. By this model, the project team can easily visualize who will be occupying that specific area at each time and where lay down and delivery areas will be established. By addressing the sequencing of work beforehand, the subcontractor performing the work is shielded from activity constraints (Khanzode).

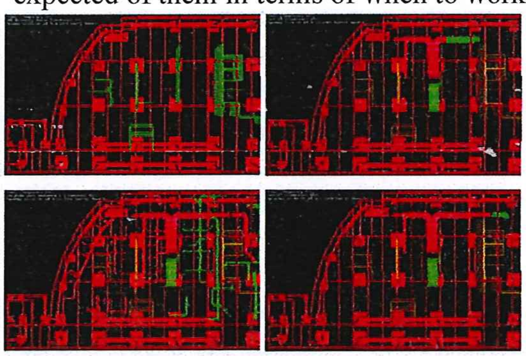

Figure 6 – 4D Modeling

Site Staging and Logistics Planning:

Through the integration of 3D modeling to site staging and logistics planning, models can be used at a macro level to resolve issues including material movement, staging, jobsite access, temporary facilities, and anything else that assists in the overall sequencing of the project.

Figure 7 – 3D Site Logistics Model

Figure 7 demonstrates how all those qualities are incorporated in a 3D model. The careful planning of site logistics ultimately will reflect positively to the productivity of the project when communicated in a clear and efficient manner. 3D modeling enables this idea to become a reality. The 3D site logistic models can be used from a general contractor's standpoint to more effectively address the flow of work to the subcontractors and also communicate with the public availability of parking and access pathways when jobsites are still being occupied by individuals.

5D Modeling:

The fifth dimension in terms of modeling incorporates 4D modeling with the element of cost. With 5D modeling, the cost value of all the various components of a building can be established. By conjoining time with cost, many different accounting scenarios can be implemented to forecast the project's budget, to help formulate cost estimates for the construction components, and to improve project control. In the design phase of a project, clients can collaborate with the general contractor with a "live" model. If there needs to be a change to the design of the project to remain in budget, the calculations of cost will fluctuate simultaneously as the overall geometry of the facility changes. This becomes very beneficial in owner meetings when answers can be resolved in a short amount of time. Additionally, 5D modeling helps optimize the effectiveness of the schedule. By providing the general contractor with resource-loaded schedules, accurate cash flow forecasts, and risk analysis, the team can accurately determine when certain tasks need to be completed ahead of others (Muzvimwe).

Educational Experience Regarding the Application of Virtual Design Construction:

Marquette University has facilitated me with substantial knowledge to properly incorporate virtual construction tools for pre-project planning. In the Construction Engineering and Management curriculum, the proper use of SketchUp is taught to model virtual mock-ups and overall building designs along with generating 3D models for site logistic plans. I have not been able to directly use BIM technology at this point in my education, but many classes incorporate the study of BIM and also various general contractors have been invited to discuss how they utilize BIM in their daily practices. Recently a project manager and a VDC expert from Mortenson Construction were invited to several of our classes to address the importance of BIM in pre-construction efforts. Marquette has also enabled me with the opportunity to co-op with Opus Design Build, L.L.C where I was able to first-hand experience how VDC is used for many of their projects. My co-op experience allowed me to truly appreciate and see how BIM is used in real life situations. Finally, the Builder's Coalition of Marquette has provided an avenue for me to attend a variety of construction visits and presentations that has exposed me to many aspects of VDC.

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