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A GRAPHICAL/GEOMETRIC (VISUAL) COMMON LANGUAGE FOR THE PRODUCTION HOME BUILDERS

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ABSTRACT
The architecture, engineering, construction, occupancy, and operations ($AECO^2$) process suffers from a lack of a common language between participants. Visualization platforms such as CAVE, linear scheduling along with the use of tools, such as PDAs, barcodes, digital imaging tools and etc. provide an opportunity to structure a common information exchange between all parties.

This paper presents some thoughts, which are extensions of research, looking at how to industrialize the construction site, funded by HUD and in association with several large production homebuilders. The paper identifies the need for a client centric approach to data development, interaction and archival with additional user specific processes imbedded within and; further, identifies the need to develop a new production planning process that more specifically looks at work flow characteristics, resource consumption and assignment. This research, finally, searches for a new platform for construction planning to achieve mass customization in housing industry through development of a visual interface that may be defined as a visual common language with a web based information technology framework.

KEYWORDS
Housing, Information Technology, Linear Scheduling, Mass Customization, and Visual Language

1. INTRODUCTION

Delivering the product as designed is one the most difficult goals to achieve in AEC Industry due to the lack of a common language/understanding between clients, designers, contractors, sub-contractors, laborers, suppliers and manufacturers. This gap, inherent between and within the design process and the construction process, blended with construction community focusing on product rather than the process has resulted in the AEC industry falling way behind in its development compared to the other industries.

In an efficient construction environment, it is vitally important to monitor and understand how information flows between project participants. Poor communication is believed to be a major reason for rework and low production. Therefore, an improved information handling system and an information flow model of all project phases are required to improve the construction process.

The Internet with its "World Wide Web" has proven to be a revolution in information flow, providing real-time access to information located around the world. These recent technologies, facilitating the instantaneous sharing/transfer/management of sophisticated databases, have led researchers to think about the development of an environment which sets the stage for linking the design and the construction processes. Visual representations, such as CAD, visualization platforms, linear scheduling along with the use of tools such as PDAs, portable PCs, barcodes, digital imaging tools…etc. provide an opportunity to structure a common information exchange between all parties.

This paper proposes a new platform, a new construction planner **to achieve mass customization in housing industry through use of advanced information technology and development of a visual interface that may be defined as a visual common language**. The proposed platform will enable a contractor to specify a house design using a product model, describe the relationships between product components and parts of a schedule, such as activities, construction equipment and crews…etc., and store this information in a web-centric environment where data can be shared/transferred/managed instantaneously.

2. BACKGROUND

Several manufacturing homebuilders and some residential house construction projects have been studied, in close collaboration with the management and procurement teams, for the development of an intense framework. The current information flows within these companies were established and the existing level of drawbacks in information handling as verified by requests for information, change orders and rework correspondingly, have been studied. It has been concluded that the design process is standardized in most of these companies and option modules are similar across designs, hence, inducing project managers to reuse schedules. This initial survey determined the apparent problems with information transfer and identified the areas where detailed data was required for re-engineering. It has been observed that current forms of production and project management focused on activities and ignored flow and value considerations. (Wakefield and O'Brien, 2001)

In present construction planning approach, a project, customarily, is viewed as being composed of subprojects which in turn may be regarded as being composed of sub-subprojects and so on. The subprojects, according to Carmichael and Wakefield (1994), might be broken down according to phase, work type, work parcels, contracts, regions, organizational structure and (existing) cost codes, cost centers, and cost headings. At the lowest levels of this hierarchical breakdown of a project the entities are individual activities or tasks that are of relatively short time span. The lowest level is that for which time, cost and resource estimates can be associated with individual activities.

This activity-focused approach hides the waste generated between continuing activities by the unpredictable release of work and the arrival of necessary resources. Additionally, the project participants are treated as discrete elements of the chain and the effects of dependence and variation along production are disregarded. It is obvious that to acquire a solid empirical basis and understanding of the relationships and practices in current construction processes, alternative approaches should be developed in terms of systems integration and work breakdown structures.

This research focuses on the impact of design and construction integration on the process of delivering a house, hence, improving its quality in terms of customer satisfaction. A similar approach was proposed by Love et al (1997) on facility construction projects. Love et al developed a quantitative model to measure design and construction integration and its impact on construction. Another study has concentrated on the integration of 3D CAD with project databases, hence, enhancing the functionality of decision support tools (Songer et al, 1998). In this study, Songer et al concluded that the data and systems to be implemented should be clearly defined and simple for the integrated design and decision support tools to achieve true efficiency.

The timely completion and success of a project rely on good planning and a good schedule. Contractors who repeatedly build the same kind of facilities, like in residential construction industry, acquire experience in planning the needed construction work. The previously developed production plans could possibly be reused to help plan future work hence, not only determining the systematic procedures required for optimum strategies, but also making due allowance for process delays and other disturbances for determining likely project durations.

The use of web centric IT systems for construction process modeling, where all modeling elements are implemented as objects with integrated functionality, can provide many advantages by linking these models with other knowledge-based expert systems (Fisher et al, 1998). These models will also help the project team to identify and eliminate non-value adding activities by determining the optimal activity cycle time, the most appropriate procurement system and information flow strategy for a particular project and the most effective balance of resources to meet the requirements of the project.

Web-centric PM tools provide a practical means of analyzing construction processes to identify resource utilization and idleness, operation bottlenecks, productivity, and operational costs (Tilley et al, 1997). The paradigm of IT system design can provide many advantages over traditional design, such as realistic resource tracking, precise schedule control, and linkage with other knowledge-based expert systems (Rojas and Songer, 1999).

The overall strategy is to develop advanced innovative process/production technique, which may be applied in practice to increase speed of delivery, to reduce waste of resources and to increase quality in construction activities through the integration of construction specifications, schedule, costs, Quality Assurance (QA) / Quality Control (QC) guidelines, and the whole construction database.

3. THE GRAPHICAL/GEOMETRIC BASED VISUAL COMMON LANGUAGE (G^2VCL)

The graphical/geometric based visual common language (G^2VCL) will provide easily understood navigation and orientation aids. The client is a good place to start if we want to improve communications. A ***client centric*** G^2VCL allows the acquisition process to be visually based such that the client better understands what they are getting (Beliveau and Cakir, 2001). The client/user will be provided with home options, selectable site/lot information that contains terrain model, adjacent home capability, soil and utility conditions and etc, each of which are visually presented objects. The CAD software will recognize the home as an assembly of unique components, and will link each of these components to a set of attributes. The software will then list initial costs; maintenance/operation costs and delivery times based on the design options chosen. Moreover, these data can be linked to manufacturer reports to provide qualitative information besides the quantitative data. Only the initial client centric approach is presented below in Figure 1 due to the space limitations.

Once the initial cost, maintenance/operation costs and delivery times are listed, homebuyers will take a virtual tour of their own custom home and finalize their decisions on design and cost issues. In future, client can select options, play with lots and building types and even drag furniture by using web-based systems before coming to a salesperson. In the long term the client may never meet the salesperson if the contract is managed completely through the web. After customer and salesperson reach an agreement, the data information for the Enterprise Resource Management and Planning (ERM&P) will be queued and sent to all enterprises needing the data.

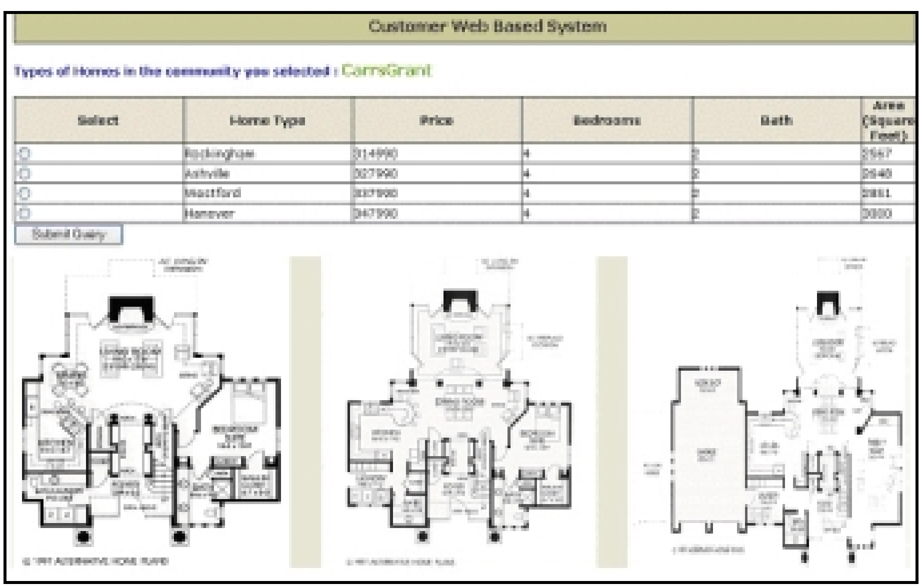

Figure 1: Plan Selection

Given an easy to understand navigation/orientation structure to the common language, the user simply will be able to truly understand what is going to happen, how it should be done, and then through time will be able to make decisions on how to better make the process more productive. The data will be interpreted for each user/enterprise distinctively and users will be able to access the needed information, make work assignments, communicate with adjacent users, and get about doing the task. As an example, the navigation and orientation information for a worker will be about the project, the location of interest within the project, the assembly of interest, and the task of interest for the worker. As a further requirement for the worker, the G^{2}VCL should have true dimensional information, assembly process, and specification information imbedded directly within the presented information. This requirement will be fulfilled by the assemblers in the field having PDAs with wireless data links, bar code scanners, and they will have access to connection details and each home's unique plans and specifications.

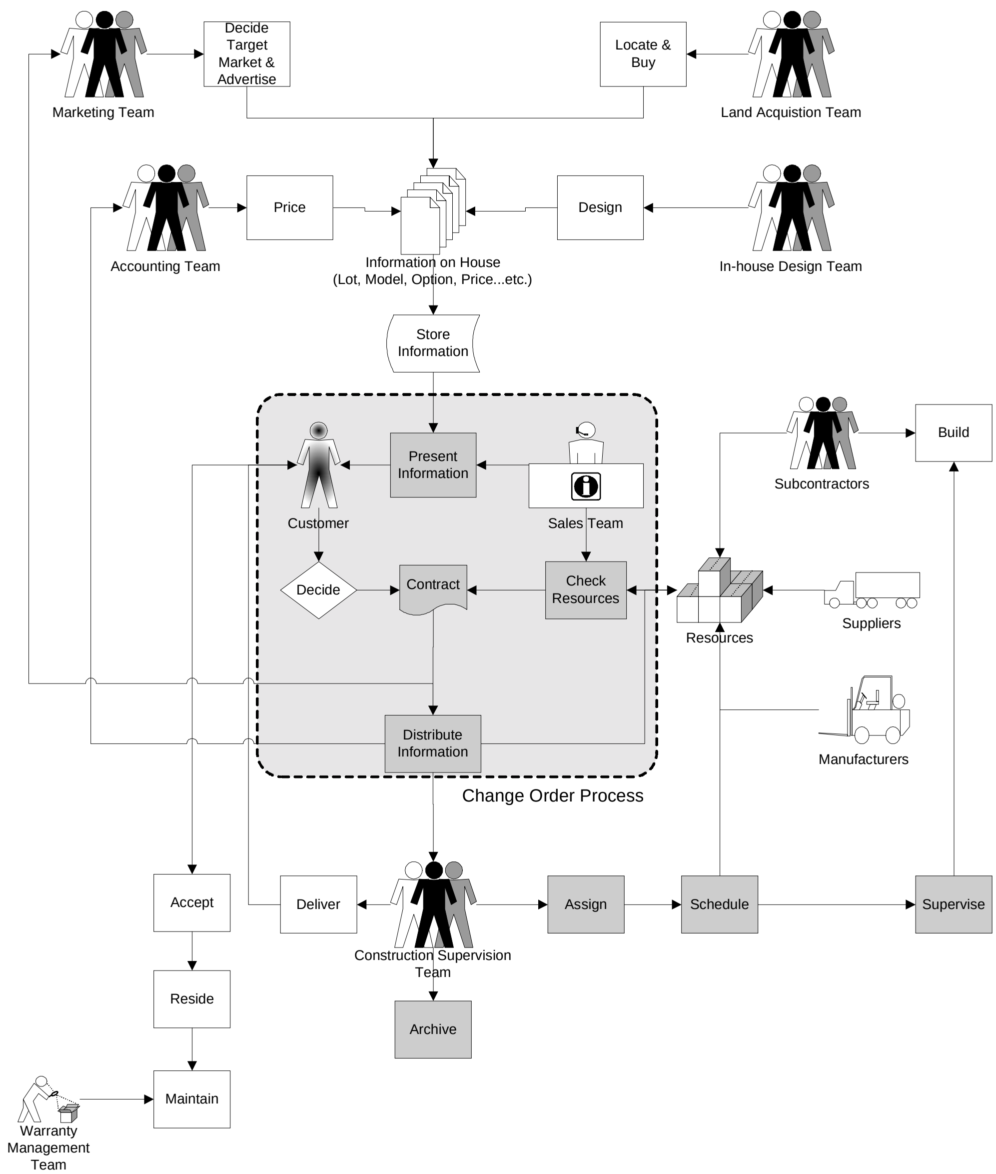

Figure 2: Process Flowchart in Production Home Building Industry

The development of the G^{2}VCL aims to eliminate two prevailing issues, that cause adversity during the AECO^2 process, that are ***change order handling process*** and the ***lack of a true production plan.*** These will be discussed in turn below.

3.1 Change Order Handling Process

Changes during construction are, often, a result of lack of communication during client to designer/constructor contacts. The client simply does not understand what they are getting. Consequently, in order to reduce changes during construction, we should build our G^2VCL to first and foremost be client centric. Client related development and a process understanding for each user of the overall G^2VCL must also be prepared. The G^2VCL system shall also allow the client interactively to give change orders when it is possible. Every customer will have a track number. Change can take place but pricing is dependent on the status of work (change order rework, lost time…etc.). Visual interfaces will show completion status, or if materials are on route or in storage. If complete order is in process, change option will change visual nature reminding the client that the change cannot be applied or if applied at a significant cost.

3.2 A True Production Plan

In order to achieve the objective of the framework for G^2VCL a Modified Linear/Paced Production Schedule (MODLIN) is proposed. As customer orders are taken, site plan, CAD modules, and MODLIN become the entry points to data/information about each client and/or project. A visual information link from production planning to process (task) will be provided and process/task level information will be controlled through the *visual planning tool* that is electronically interactive. Information flow between scheduling and resource data will provide a means of early resource planning based on crew availability and capacity. MODLIN will be used to illustrate and control the resource flow between residential units within the required production rate or line of balance. Based on this method, management will be able to input different production rates and identify labor inadequacies that will arise for the scenario given. In providing a means for trial and error prior to construction, prospective problems can be addressed well in advance.

In preplanning, management considers the volume of homes to be produced for the next year based on the company business plan, market demand, resources, economic influences, etc. Based on the annual volume decided upon, a monthly production rate can be calculated based on a linear relationship. The production rate represents the line of balance among construction activities required to meet the desired annual construction volume. Individual activity production rates can't exceed the overall rate due to lag involved in awaiting completion of the preceding activity.

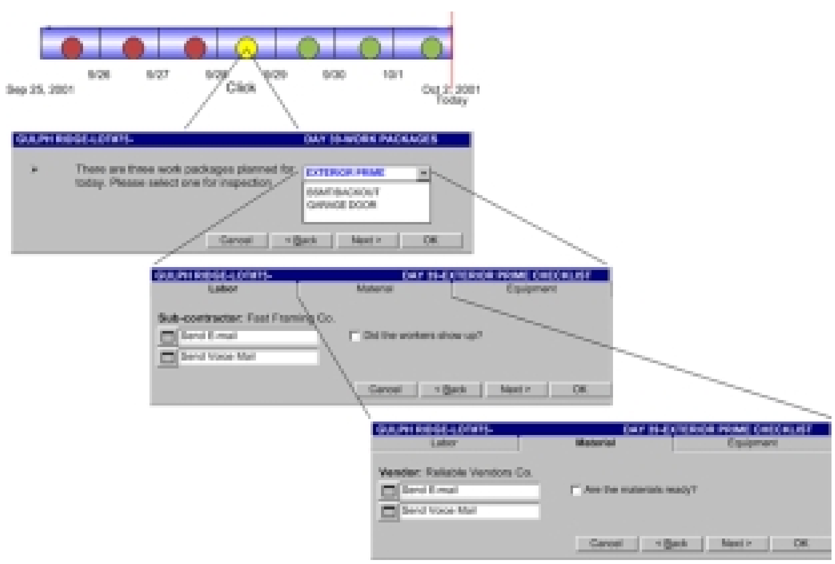

Figure 3: Field User Interface

An access path to the information needed for a specific house will be developed. Linking each activity within MODLIN for each client/unit and time will do this. When the production managers uses the portable PC or palm top with wireless internet access, they will get information about the client, the schedule, 3-D model of the house linked to the schedule, list of contractors, what is supposed to be happening, what is late, what is ahead, etc. instantly via www. A daily updated tracking process on active or completed items will be recorded by checking buttons with different colors (red for the incomplete and green for the completed task, etc.) for the list of activities and units to be completed each day. Some parts of the proposed interface are presented above in Figure 3. This tracking process may be automated with the use of electronic punch cards, which will be given to head of construction teams responsible for different trades, swiped through control units located at each lot. This will provide for supervision of the work via the web by all the participants of the work from superintendent to production managers and to the client. The utilization rates in the subcontractor database, for example, will indicate to management if specific trades are being under or over-utilized based on the inputted production rate. Based on these findings, management will be able to:

a. Readjust the production rate.
b. Hire additional subcontractors.
c. Extend the house construction durations to account for wait time on crews.

4. IMPLEMENTATION

In order to accomplish the research objective and develop the proposed framework, the following will be studied:

4.1 Development of a network logic diagram

Activity order in the network will implicitly define sequential constraints of individual activities while managerial and repetitive constraints will be identified and defined based on field input. In establishing a framework, it is necessary to define the schedule activities and sequence in a network logic diagram. Activity attributes including duration, interdependencies, technological constraints, and resource requirements will dictate the logic relationship in the network. Resource requirements include trades, material, space, equipment, and cost. By identifying these requirements, a basis for establishing possible trade flow and subsequent resource constraints is available. The network diagram will reflect activity logic identified by the companies as well as logic based on the identified constraints.

4.2 Identification of Process Constraints

Network activities will be grouped based on identified crew involvement, termed primary processes. Constraints between the primary processes will be identified and prioritized. Identified constraining factors will be categorized as general and repetitive. General constraints are inclusive of resource, spatial, technological, and management imposed constraints. Repetitive constraints control the flow of resources from one unit to the next dictating work continuity. Use of the Linear Scheduling Method and the Line of Balance Method will facilitate the ability to control workflow with regard to identified constraints as well as adjust to desired production requirements (Halpin and Woodhead, 1998). A framework will be developed that will facilitate the scheduling of trade flow across multiple homes as well as tracking of construction activity for managerial purposes.

4.3 Development of the Process Model for MODLIN

After breaking the logic network into discreet processes, each process must be represented by an oblique line. Lines depict the process' duration, production rate, and scheduling date. The relationship between the line of one process and that of another is dictated by constraints associated with the processes. Process constraints define the behavior of one process with another. The overall rate at which all units are constructed is based on the production rate set by the upper management.

4.4 Implementation of the Computer Prototype

A computer prototype will be developed to employ the proposed framework and to illustrate the main contribution of the research. The prototype will illustrate the user interface for MODLIN as well as the support modules. The authors will utilize CAD modeling environments (e.g. AutoDesk AutoCAD), database applications (e.g. MS Excel, MS Access), scheduling applications (e.g. MS Project, MS Schedule+), and web development tools and languages (e.g. MS FrontPage, Macromedia Flash, JAVA, HTML, XML and etc.). Programming will be, mostly, used for the integration of these different virtual environments.

4.5 Industry Review and Feedback

In order to validate the proposed research, the authors will attempt to demonstrate the implemented computer prototype to industry professionals, preferably who were interviewed or observed for data collection. The authors, also, aim to document the feedback as recommendations for future research.

5. CONCLUSION

Creation of interactive and visually friendly user interface is the core of this research. This system uses a hand-held/PDA device that collects information for construction inspection and documentation and allows more complete documentation of construction progress, problems, and innovative ideas. This device allows wireless two-way communications where data can be transmitted to and from the host computer. All data can be uploaded into the device and can later be stored digitally in the project server with full indexing and cross-referencing capability with the help of HTML and JAVA Scripting Languages.

Instant and truthful sharing of construction information will, hopefully, develop trust among project participants. As uncertainty is embraced, the production planning will be employed to make release of work to the next crew predictable. Partnering and close coordination with specialty contractors will shift construction management from a centrally controlled push function to decentralized pool. A contractor will be able to shift labor between nearby projects, as it is possible to project the actual demand for labor in advance. In the long run, it is not going to be too unreal to talk about web-centric labor pools, in which laborers are determining their working times and desired working regions, enabling project managers to pull the desired amount of labor force upon necessity.

Real time design and manufacture is the envisioned next step. Regardless of whether the design consists of extemporaneously thought-out elements or pre-designed components, the ability to create a virtual artifact and link it to the real activity, or house, or project for the purpose of design, manufacturing, facility management, and production management will provide a powerful tool.

The eventual goal can be a real building that adapts to the users' needs through user-initiated instructions affected by the manipulation of the buildings virtual building counterpart. Initial construction and subsequent renovation can eventually utilize automated systems, which may be brought in as a tool or are incorporated into the components of the building itself.

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