

# Requirements and Benefits of Interactive Information Workspaces in Construction

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## Abstract

This paper envisions a new type of construction information technology - construction information workspace (CIW) - that enables project teams to visually interact with project information to support the decision-making process. We introduce a set of visualization and interaction functional requirements for CIW that will provide teams with the ability to visually interact with relationships between project information. These requirements stem from three research efforts: observation of today's paper-based workspaces, observation of a 4D workspace on a construction project, and prototyping of an interactive information workspace. These observations show the potential opportunities and benefits for the use of CIW such as improving the utility of project information and improving decision-making.

## Introduction to Information Workspaces and Workspace Tasks

Workspaces are physical or virtual spaces where people work, share and use information. The world-wide web and online project management environments are virtual workspaces that enable project teams to use and share information online. However, online environments typically focus on supporting information management and analysis tasks and ignore the critical role of supporting the project teams decision-making process.

People organize their physical workspaces to support tasks to find and access information. People use different techniques such as sticky-notes, colored folders, or bulletin boards to quickly find relevant information or take notes. Similarly, we envision that electronic or interactive construction information workspaces can be designed to use visualization and interactive techniques that support these decision-making tasks.

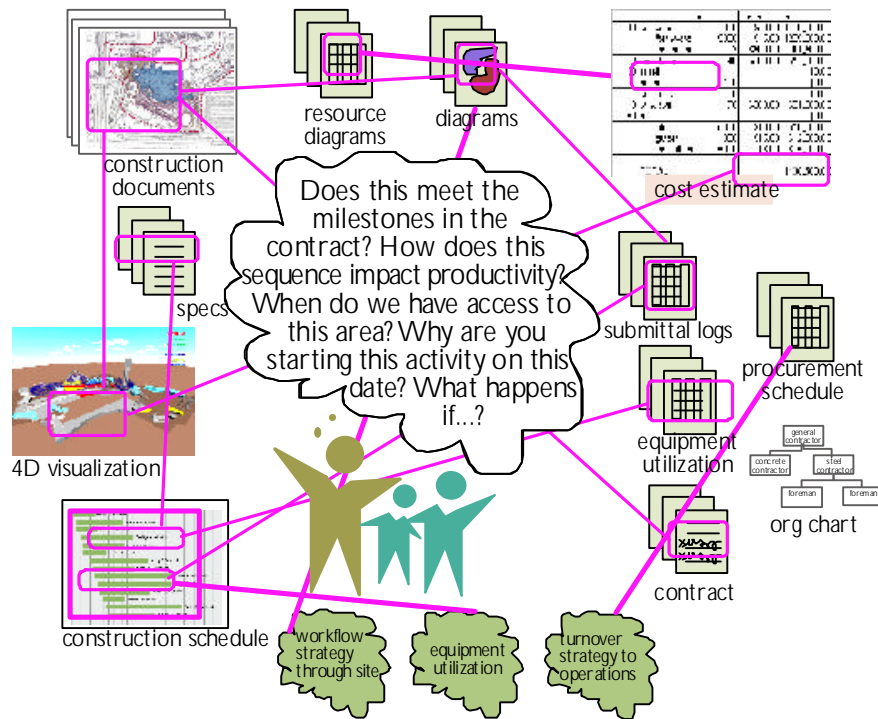
In the following sections we discuss our initial set of requirements and potential benefits for these environments based on 1) our observation of workspaces today, 2) observation of 4D workspaces, and 3) prototype and observation of use of an electronic information workspace (Figure 1).

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**Figure 1: The Decision making process as a set of tasks/questions to describe project information, explain relationships between project information, evaluate relationships between project information and predict impacts of changes on project information**

**Information Workspaces Today**

Construction project teams must consider a wide variety of information when making project decisions (Figure 1). Walk into any construction project meeting and you will find many examples of the types of paper-based project information teams use to make project decisions. Today, construction teams typically work in physical workspaces such as conference rooms. Although much of this information is produced electronically and visual in nature, teams primarily use paper-based views of project information to share information with each other in project meetings. These views often do not communicate critical relationships between project information or adequately highlight the important and critical information. Consequently, project teams spend far too much time trying to understand and describe project information to one another and are unable to leverage existing information to support decision-making and solve problems. Consider the following schedule review meeting for a major construction project in Southern California we observed:

*On the walls of the conference room are 2D construction drawings and the project Gantt chart. Each meeting participant has handouts consisting of the schedule, which contains 8,000 activities, and the meeting agenda. Participants have brought other types of documents to the meeting such as 'marked-up' schedules, some contract documents, and construction*

drawings. The meeting begins with the first agenda item, 'Schedule Comments.' This discussion involves the owner asking questions such as: Does the schedule meet contractual milestones? Do these activities adhere to project specifications? Why are you finishing this facility on this date? What if we change this milestone date? What if the equipment is late? Throughout the meeting, project participants are distracted as they shuffle through the schedule sheets searching for activities or as they scan the walls searching for relevant information, trying to understand the schedule and the issues at hand. Meeting participants come and go. Some leave to get information such as project specifications or to get updated information. In some cases, a document is passed around for participants to review. By the end of the meeting, twenty types of documents have been referred to or used as participants try to describe, understand, explain, and evaluate the schedule. Although several problems are noted, and issues or potential solutions discussed, no problems are resolved during this meeting nor during the successive three meetings.



Paper-Based Workspace



4D Workspace



Future Workspace Room

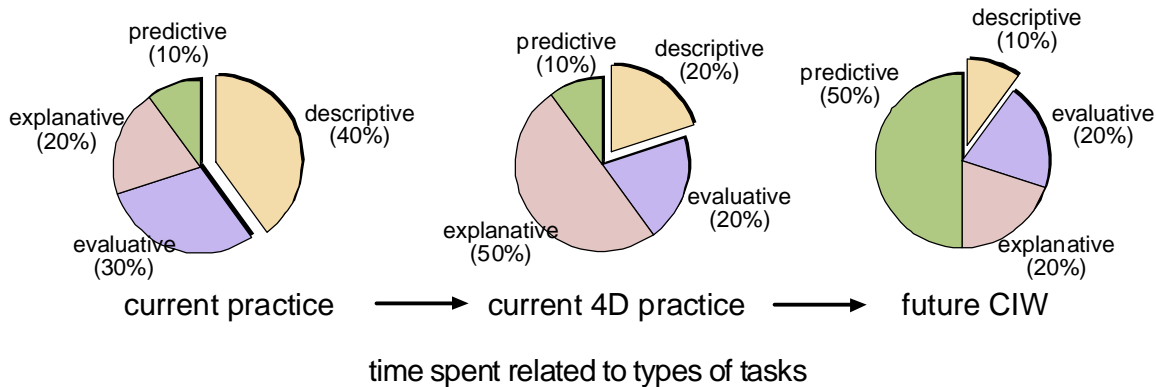
**Figure 2: Snapshots of Workspaces. Today's Physical Paper-based Workspace, 4D CAVE Workspace, and Interactive Information Workspace**

Did the project information support the team's ability to make decisions, and did the team effectively utilize the information they produced? No, since the team was unable to make any decisions and they spent more time trying to describe, explain, and evaluate the information than using the information to support decision-making. Our observations of project meetings show that teams spend most of their time on descriptive, explanative, and evaluative tasks - tasks that support the decision-making process - and approximately only 10% of the time performing predictive tasks or the critical "what-if" tasks that lead to better decisions. More importantly, teams rarely completed these predictive tasks in group settings. When they did, our observations showed that the reliability and accuracy of those tasks was low since team members often commented that the information was out of date or that they were uncertain of potential impacts to project activities and objectives. That is, for tasks dependent on a wide variety of information there was a low chance of the team completing that task or completing it reliably.

From observing many design and construction review meetings, we concluded that construction information workspaces must be designed to support the following tasks necessary for decision-making:

- **Descriptive tasks:** Describing the 'who', 'what', 'where', 'when', and 'how' of the project. Traditional schedule methods, such as Gantt charts, use temporal relationships in a Gantt chart between construction activities to describe 'when' and 'what'. Some schedule tools allow teams to relate activities to resources, thus describing 'who' and partially 'how'. 4D visualizations relate the spatial and temporal aspects of a project, thus enabling teams to communicate the 'when' and 'where' of a project.
- **Explanative tasks:** Explaining project decisions or the schedule rationale - the 'why' questions. Most tools do not enable teams to capture or document 'why' decisions are made. Typically this information is expressed as constraints, e.g., resource constraints, contract constraints or procurement constraints.
- **Evaluative tasks:** Evaluating project goals and checking that project requirements are met, e.g., 'does this meet this requirement' or comparing one set of information against another set of information.
- **Predictive tasks:** Predicting impacts of changes or specific decisions on project goals - asking 'what if' or 'what happens to' questions.

All these tasks are critical to enable project managers to make decisions. Our work assumes that the ability to make decisions is directly related to a team's ability to perform these tasks. More importantly, making good decisions is most directly influenced by the team's ability to perform predictive tasks. However, our observations of project meetings show that teams spend most of their time performing descriptive, explanative, and evaluative tasks (Figure 3). Therefore, the goal is to measure whether improved workspaces enable a project team to do more predictive tasks. As discussed below, our initial experience in using interactive workspaces to support project meetings suggests that project teams do, indeed, perform more meaningful tasks when working in interactive spaces.



**Figure 3: Breakdown of Time/Task comparing today, 4D workspace, and future workspace**

Our requirements for interactive workspaces are derived by asking two questions:

1. *Does the workspace help project teams to make decisions?, i.e., does it support the tasks noted above?*
2. *Does the workspace enable the team to utilize the electronic information the team produces?*

### **Lessons Learned: Today's Workspaces**

Physical, paper-based workspaces do provide value to teams that virtual computer information spaces or desktop environments do not (yet) provide. They enable the team to display a wide variety of information so that multiple stakeholders can participate simultaneously in the decision-making process. CIW, then, need to maintain the following functionality of today's physical workspaces:

- Display a wide variety of information simultaneously
- Display overall scope of project in context of detailed

Yet, our observations also highlighted the need for the following functionality to support decision making in group settings:

- **Interact with project information.** Most design and construction tools today do not make it easy for casual users of the tools to interact with the project information. As a result, team members have to resort to hand waving when describing a new scenario during a meeting.
- **Generate group appropriate views of project information and foster multi-stakeholder participation.** In the case, the Gantt chart provided an overall context, but was unusable for any group task. Team members stood in front of the chart, searching for relevant activities and pointing to activities that then caused other members to search through their own personal schedules for the information. In general, current printed views of project information are designed for individual, domain-specific review and not group review.

- **Communicate critical relationships between project information and visually integrate project information.** During the meeting, as a team member described certain activities, the member would walk to the 2D view of the project and point out 'where' the work was taking place. Similarly, when the team wanted to compare information in the schedule to contract requirements or project specifications, various team members had to search through documentation to identify the related items. Relationships between time, space, resources, project requirements, and cost are not captured or communicated in today's traditional graphical representations. This forces the team to spend time comparing and trying to understand how the information is related, when simple visualization techniques might easily communicate this information. Views don't visually communicate critical relationships between project information, requiring project participants to manually integrate project information in their minds. Instead, a CIW should generate views of project information appropriate for groups to foster multi-stakeholder participation.
- **Highlight relevant information to improve focus and reduce distraction.** Since much of the information that the team used or referred to during the meeting, such as the project specifications, diagrams, detailed schedules, was private, the team rarely focused on the same information. Even the shared information, the 2D drawings and schedule, provided no visual cues to guide the focus of the team. Consequently, project participants were easily distracted.

#### **4D Workspaces**

On the same construction project, we participated in an R&D project using a 4D-CAVE environment (Figure 2) that enabled the team to visualize relationships between time (construction activities) and space (3D model of the project) [Schwegler et al. 2000]. Several project review meetings took place in this 4D workspace, a CAVE environment [Mahoney 1999].

*The team meets in a 4D-CAVE (Fig. 3), which displays a real-time interactive 4D visualization of the project schedule. The team first reviews the schedule by playing the 4D schedule, day by day and viewing the different kinds of construction activities taking place, as indicated by color. At various points in time, specifically at milestone dates, shown in pink, the team stops the 4D playback and navigates through the 3D model. Questions relating to the rationale of the schedule are asked, such as why certain activities have to finish at certain times, or why the sequence of construction goes from north to south. Additionally, the team discusses work constraints in several areas and identifies and solves several problems.*

During these 4D meetings, the team spent more time explaining the information than describing it, an improvement over the traditional paper-based meetings. They were able to quickly identify several problems and solve some of them.

#### **Lessons Learned: 4D Workspaces Today**

This environment demonstrated how:

- interactivity helps teams to more efficiently navigate through the information
- shared visualization improves focus, there was no paper and everyone focused on the 4D visualization
- visualizations can communicate relationships between project information
- large-scale views are more appropriate for group tasks.

These improvements from using a workspace environment that communicated time-space relationships is motivation to continue to research how new ways to visualize project information will improve group tasks and decision making. This experience also demonstrated the need for functionality that would enable the team to:

- navigate through and interact with the information in various ways. The 4D workspace allowed only temporal and spatial navigation. The team would have liked to navigate by browsing a hierarchy of components in the model or by type of work or work assignment. They would also have liked to interact more directly with construction-specific components, such as laydown areas or construction equipment to explore ‘what-if’ scenarios.
- focus on specific information in the 4D visualization through additional visual cues.
- visualize additional kinds of project information, such as cost, work assignments, procurement information.

### **Interactive Information Workspaces Today**

During the past year we have prototyped an interactive workspace environment (Figure 2). This environment utilizes workspace technologies developed and funded by the Computer Science department at Stanford University [Winograd and Hanrahan 1999]. Our initial prototype demonstrated two key types of functionality: electronic interactive display of multiple types of project information and annotative visualization techniques. Liston et al. [2000] describe these visualization techniques, and Froese and Yu [2000] describe approaches to the implementation of this functionality. The following is an example scenario of the CIW functionality needed for a construction project team:

*On the walls of the room are electronic views and icons representing various project information, such as the schedule, the 4D model, and project status information. Instead of a paper agenda, there is an electronic agenda that associates each item with the relevant information, that when selected highlights the relevant project information. The CIW also displays all of the available project documents and information. In the CIW any project information can be overlaid onto a spatial or temporal view, thus enabling team members to quickly view relationships between project information. For example, the team can easily compare contract requirements against current project information by overlaying information onto other information. Thus, the team doesn't have to spend much time on these comparative tasks and can spend more time reviewing and evaluating the information. The team can easily view critical relationships between the information views because related items in the 4D view, Gantt chart view, cost view, and resource view are highlighted. As problems are identified, the team can quickly understand the constraints and rationale of a particular solution and explore alternatives by making changes to project information and quickly viewing the impacts of those changes on other project information. The team leaves the meeting with a shared understanding of the issues discussed and is satisfied with their solutions.*

### **Lessons Learned from Interactive Information Workspaces**

Today, only a small part of this vision has been realized through the efforts of the Stanford Interactive Workspace project. Our initial prototype efforts in this environment have implemented the following types of user functionality:

- View a variety of information
- Interact with information in direct and intuitive way

Our prototype efforts also illustrated the need for the following functionality requirements:

- standardized tools for viewing a variety of project data
- visualization techniques to relate views and project information
- interaction techniques to navigate through the information space and move between levels of detail

### **Potential Benefits of Interactive Information Workspaces**

Our research goal is to design and implement a prototype CIW that incorporates the functionality requirements described in the previous sections. This CIW will:

- *improve a team's ability to make critical project decisions.* With useful, interactive views of information teams will improve their ability to describe, explain, and compare project information. Once teams can perform these tasks more efficiently, they will be better equipped to make decisions and leverage the team members' expertise and creativity.
- *improve the utility of project information* since relevant information and needed information will be available to project teams in the decision making process.

We are currently developing a second prototype CIW that focuses on the visualization functionality requirements described above. We are evaluating these visualization techniques based on these perceived benefits [Liston et al. 2000]. We are also involved in efforts to implement the underlying architecture as described in Froese and Yu [2000] to address some of the functionality requirements for data exchange. Research efforts by Terry Winograd and the workspace group will address the interaction functionality requirements noted that is useful beyond the construction domain

In summary, more interactive information spaces will allow project participants to leverage the investments in information modeling and visualization by themselves and by others. Intuitive user interfaces will enable far greater numbers of stakeholders to participate in the development and evaluation of project alternatives. Hence, such interfaces may well become the main driver for the development of technologies to integrate project information.

### **Acknowledgements**

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