BEYOND WEBCAM:
A SITE-WEB-SITE FOR BUILDING CONSTRUCTION

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ABSTRACT: The use of project website and web cam technology in the construction industry is limited to providing basic information about the project and 24/7 pictures of the site. This paper discusses the promises of a site-based website that serves as the central hub for real-time communication, monitoring, and control in building construction. Such a website offers opportunities that go further beyond what is in use today. The paper lists a series of possible applications that have been tested at several construction sites in Raleigh, North Carolina. In addition to helping contractors plan and control the resource flow in real time the site-web-site is also used as a tool for creating daily reports, rapid problem solving, remote inspection, productivity measurement, on site security, communicate with on-site equipment (e.g., in emergencies), and to create visual as-builts.

KEYWORDS: collaboration; productivity; Internet; logistics; value; website; equipment; safety

Introduction

According to U.S. Census Bureau, in 1997 the construction industry performs more than $845 billion of work or almost 11% of GDP and employs more than 5.6 million employees. Thus, construction productivity is important for the growth of entire U.S. economy. However, statistics show that productivity of the construction industry has been far below other industries for the past three decades. In addition, productivity is not the only problem facing the industry. Quality of work, waste, and safety are among the issues that decline the industry's overall performance. Therefore, increasing productivity, improving quality, minimizing waste, and providing a safe environment for workers are main the goals in managing a construction project. In order to achieve these goals, attention must be paid to the planning and controlling of the processes rather than on assessing, measuring, and repairing after the product is finished. In other words, it is only before and during the actual operation that management has the chance to intervene and correct, ensuring optimal performance under the given circumstance. This, however, requires real-time and accurate information coming from different sources.

With today's digital and world-wide-web technologies, communication has never been easier and faster. The construction industry has adopted web technology and some projects already have their own websites. Nevertheless, the application has been limited to providing basic information such as project participants, construction area, and contact information. Some projects also have a web cam to provide real-time pictures of the site. However, by integrating the web with other technologies such as wireless, sensor, and tracking devices, the project web site can be transformed into a powerful tool for every participants to plan and control. Because the potential use of the technology is limitless, it is imperative to investigate the benefits they could provide to each user. This paper discusses the promises of a site-web-site (SWS) that serves as the central hub for real-time communication, monitoring, and control in building construction. Such a website offers opportunities that go far beyond the conventional project website and web cam.

Coalition Building: A Win-Win Strategy

The SWS is designed for six major users: 1.) Owner, 2.) Designers, 3.) Inspector, 4.) Contractors, 5.) Subcontractors, and 6.) Suppliers. Prerequisite of the successful SWS is open information sharing between participants. Unfortunately, the sharing of information is very uncommon in an industry that is constantly squeezed by the low-bid mentality of the owners. Low-bids foster a zero-sum culture where everybody fights for a piece of a small pie without considering how his piece is connected to the much larger pie. If we can't change the zero-sum strategy of contractors, the main benefit of web-based communication network will be lost. Thus, this paper will first develop a concept that could entice contractors, suppliers, and subcontractor to build coalitions as a framework to share information using a site-web-site (SWS).

Collaboration between contractors and suppliers of a building project offers to drastically improve productivity and cut resource waste. The basic premise of a contractor coalition is to cut the cost of operation for the participating coalition partners by optimizing the use of the combined resources. Figure 1 presents a simplified comparison between a competitive and collaborative approach. As indicated, the overall benefit or the value of collaboration is $20 ($150 - $130). This gain, however, can only be achieved if the supplier spends $10 more on his operation when compared to the traditional method. It is apparent that the only beneficiary of the coalition is the contractor who shows a net gain of $ 30. In order to make collaboration attractive to the supplier, the contractor has to be willing to share the savings, which he really can only achieve with the added work of the supplier. If we assume that the two coalition partners are splitting the gain equally, the supplier will be reimbursed his $10 extra cost and receive an additional $5 from the "coalition fund" reducing his actual cost to $45 compared to the $50 in the competitive mode. The contractor, on the other hand, will end up with a cost of $95 vs. $100. Figure 2 highlights a real world application of this concept.

In a comparative field test Salim and Bernold (1994) showed that through up-stream planning, rebar could be bundled and shipped according to the way the rebar is placed. If the rebar is staged properly, as indicated in Figure 2, ineffective time spent on re-handling and searching can be eliminated. The result of the study showed that placement-oriented delivery and staging improved crew level productivity in the placement of rebar by 30% compared to the traditional method. Key to the productivity gain in laying the bars, however, was a supplier who was willing to collaborate with the subcontractor in shipping the steel in a way that matched how the crew was progressing.

Framework of the Site-Web-Site (SWS)

The main objective of the SWS is to providing an electronic hub that allows the real-time sharing of information between collaborating entities. The system consists of a notebook computer with broadband Internet access as a hub and a set of peripherals such as docking station for PDA, motion detector, and video camera. The camera used can be wire or wireless. The wireless camera provides more flexibility but the drawback is poor clarity of the picture. In addition, the series of digital picture have also been taken and keep in the website as a project history. The information maintained in the system is visual and media rich. The system has been tested at the residential building construction site in Raleigh, North Carolina. Furthermore, the extension of the system is limitless. As shown in Figure 3, the list of integrated transmitters, receivers, sensors, data entry ports, access portals, etc. can be extensive. It is also indicated that on-site data communication using wireless technology will make the system extremely flexible.

Applications of the Site-Web-Site (SWS)

The following section describes several possible applications for SWS.

Synchronizing the Resource Supply

The Council of Logistics Management (CLM), defines logistics as a part of the supply chain process that plans, implements, and controls the efficient, effective flow and storage of goods, services, and related information from the point of origin to the point of consumption in order to meet customers' requirements (CLM, 2001).

In addition to the physical material, information about the material such as: 1) bill of material, 2) purchasing order, 3) specification, 4) delivery date, and 5) staging area can also be modeled as a flow. Figure 4 presents a schematic that indicates that besides material, all the resources necessary to complete a process can be incorporated into a flow model that links the Point of Origin (POO) of a resource to a point of consumption (POC). It is apparent that the goal of a synchronized resource logistics model is to ensure the availability of all resources, at the right time, at the right quality, at the right quantity, at the right place, for the right price. As the example of placing rebar indicated, optimal resource logistics in construction offers many opportunities for collaborative cost savings, since many of the resources are controlled by independent business entities. Web-based resource logistics offers a unique technology that supports such coalition building.

24/7 Visual Site Access

An example website that includes the picture from a web cam is presented in Fig. 5. The interval time for refreshing or storing pictures can be set from 1 to 10 min. Some of the most common benefits of such a technology include:

- Real-time review of project status from anywhere w/internet access
- Automatic recording of environmental conditions, project progress, etc.
- Rapid problem-solving if visual information is needed
- Automatic surveillance at night if connected to a motion detector and light source

Visual Inspection

Many inspections required during construction are visual. Figure 6 features two digital images during and after the completion of the foundations for a single family home. In the same vein, SWS would allow company safety inspectors to do their visual inspection remotely.

Visual As-Builts

One unique opportunity provided by SWS is the creation of visually or electronically generated as-builts. Spatial data about the exact location of a new water pipe can be collected from a laser positioning system. Alternatively, digital pictures allow the new homeowner to see through the walls. Figure 7 exhibits, two examples how digital images can be used for establishing as-builts. If the inspection of the electrical and pluming system would include taking a series of digital pictures, an extremely useful information bank could be established. Another example of useful visual as-builts is the pictorial marking of buried utilities such as water, sewer, cables, and gas. Any homeowner who has changed the landscape around his/her house could benefit from the availability of such information.

Automatic Resource Tracking

The RFID (Radio Frequency IDentification) tag technology has successfully been used in the retail and service industries. For example, Wal-Mart and FedEx have implemented RFID tags to improve their supply-chain and logistics management. By using RFID tags, the SWS will be able to track and identify materials, equipment, tools, and other resources automatically.

As was discussed earlier, synchronizing the resource logistics must be one of the main goals of a concept that wants to create win-win partnerships. Since equipment, material and labor are key resources on a building site, tracking their whereabouts is essential. Figure 8 displays two situations where tracking is able to provide valuable information for different project participants. Figure 8 a) is of value to the framing and general contractor, as well as to the lumber supplier. For example, both contractors can estimate precisely when the framing crew can start and when the materials should be delivered. It would allow the framing contractor to indicate where he would like the lumber to be staged. He could do this by marking the digital picture and submitting it to the supplier. The effect would be similar to the rebar example discussed earlier in that unproductive transportation time could be eliminated.

Figure 8 b) shows that the trusses have been delivered but not necessarily in an optimal position. First, it will be necessary to separate the stacks of trusses. If no crane is available, this work has to be done by hand one truss at a time. Secondly, the staging location is not efficient because the distance to the footprint of the house is quite large. Most importantly, however, the framing contractor can see clearly the status of the framing work and the exact location of the delivered roof trusses.

BlackBox Technology

Electronic monitoring of large systems can have many different goals. One example is to detect an unsafe status of equipment while in operation. Bernold (at el., 1997) developed such a system for cranes. The intelligent monitoring system can be used to retrofit existing crane hardware. The simple architecture and the transportability of the sensors provide opportunities for utilizing the concept for other types of cranes or even for other machinery where unsafe conditions cannot be detected easily by an operator. Figure 9 depicts how a BlackBox mounted on a crane can be equipped with a wire-less communication interface to alert people or establish communication between equipment that are linked to the SWS system automatically. In addition, such information can be maintained in the server computer and be used as a historical record for the equipment.

Summary

Resource logistics, which was once limited to storing and moving of goods, has become a critical component of company management. Storing and transportation are still necessary but now these processes are seen as source of "waste" that should be minimized. In addition, logistics of goods alone is no longer sufficient. Information, considered itself a resource, needs to be part of logistics management. Because of the highly fragmented nature of the construction industry information is being created and needed by many different companies. The main obstacle to sharing information freely, however, is the low-bid orientation of the industry. Using a win-win coalition building strategy will create the necessary incentive to make a site-web-site an economically successful concept.

This paper presents a prototype website for building construction designed to help owner, contractors, suppliers, and other participants to plan and control resources in real time using 24/7 visual accesses to the site. Using a set of examples different uses and benefits of SWS were explained. The system has been tested at various construction sites in Raleigh, North Carolina. The results show promise to create an effective tool to improve communication between contractors, supplies, and homeowners. In addition to real time accesses, the system is also used as a tool for rapid problem solving, and increase security. The digital images taken at the site provide a historical record and "visual as-built" for the homeowner to show the location of utility lines both behind (inside) the wall and buried under ground.

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Mode of Relation	Cost to Supplier	Cost to Contractor	Total Cost	Cost Saving
Competitive	$ 50	$ 100	$ 150	
Collaborative	$ 60	$ 70	$ 130	$ 20

Fig 1. Cost-bene[illegible] on

Fig 2. Rebar delivered according to the sequence of placement

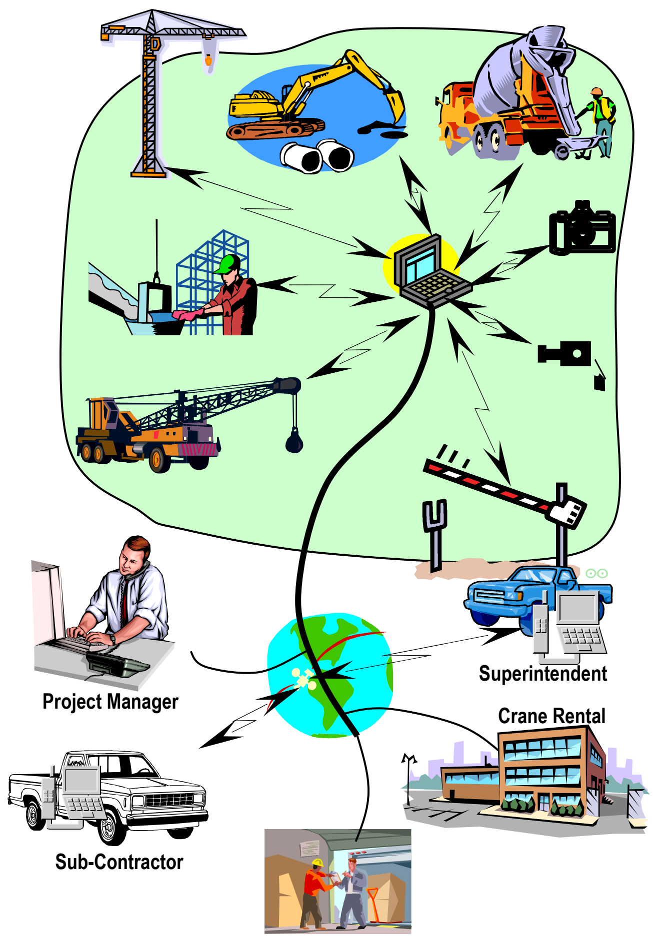

Fig 3. Communication Network of a Site-Based Website

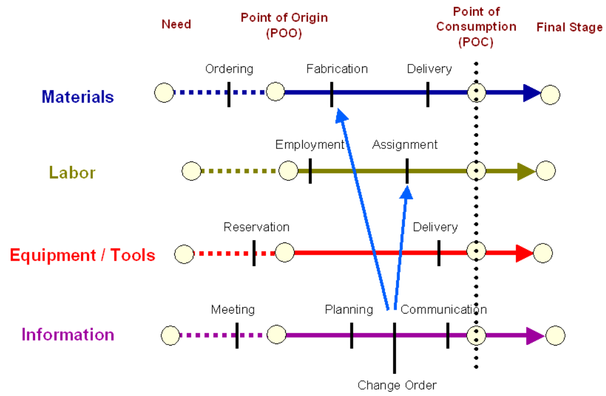

Fig 4. Integration of Resource Logistics

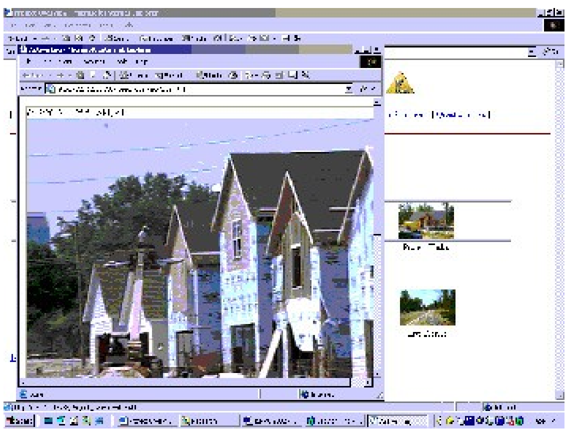

Fig 5. WebCam On a Site-Web-Site

Fig 6. Remote Inspection of Foundation Using SWS

a) Studs, Pluming, Power   b) Buried Water Line

Fig 7. Digital Pictures as As-Builts

a) Labor is Establishing Foundation Walls, Brick is Staged at Road, Bobcat is Operating

b) Wall Framing is Being Worked on, Roof Trusses Are Delivered

Fig 8. Tracking Status and Location of Resources

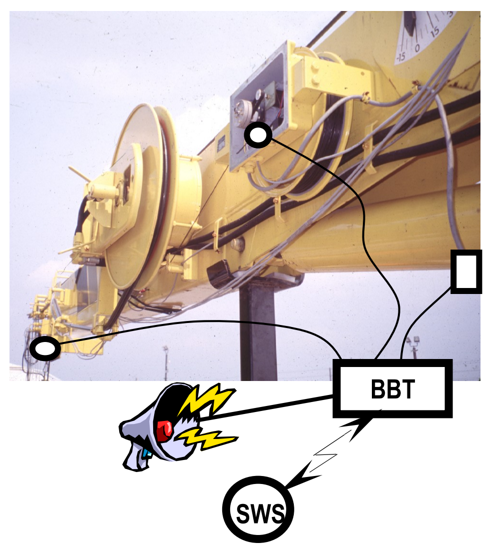

Fig 9. BlackBox Linked to SWS