PRACTICAL KNOWLEDGE BUILDS PROJECTS: CASE FOR INDEPENDENT CONSTRUCTION INFORMATION MANAGEMENT

David Gurley[1] and Bill McManus[2]

ABSTRACT

This paper argues that the management of information for construction projects should be by independent information managers whose only interest in the project is in the efficient management of information. Their responsibility focuses on setting information standards, gathering, organizing, storing and exchanging information. The resulting system must provide information that is transparent, timely, appropriate, accurate, complete, dependable, secure and unbiased. All participants must have access to and confidence in this construction information system.

KEY WORDS

Project information management, automatic information, schedule centric project management, e-construction, transparency, lean construction.

1 AIA, dgurley@ionet.net
2 University of Oklahoma, Bill-McManus@ou.edu

INTRODUCTION

Practical knowledge builds projects. To be practical, information must be reliable and accessible. Information that is not practical is "muda"[3]. Information flow is the complementary component to work flow. It is the lubricant that synchronizes and aligns the work process. Reliable detailed information is necessary for the elimination of waste (Ballard and Howell 1996). It is the management of this process of capturing and sharing information that is the responsibility of the independent Information Manager (IM). He must see to it that information flows both to and from the job site as well as anywhere else that the work is being performed. He is not the creator of the information nor is he the consumer.

There is a clear distinction between the management of the information for a project and the management of the project itself. The management of information is not project management, but project management requires efficient information management.

Francis Bacon, a 16th century English philosopher once observed, "Knowledge itself is power." Advances in information technologies are allowing unprecedented accumulations of knowledge concerning design and construction. In this paper we make a case for investing that power in a transparent information system, managed by an independent Information Manager and shared by all project participants.

Although we tend to use the terms interchangeably, there is a distinct difference between data, information and knowledge. Data are the raw byproducts of business processes. Information is data that has had value added by being organized and placed into context. Knowledge is information that has been further enhanced by being believed and understood by people.

In their book "Working Knowledge: How Organizations Manage What They Know", Thomas Davenport and Laurence Prusak explain the continuum as starting with data, moving to information and ending with knowledge. In each step, value is added and the result becomes more closely tied to human beings. Essentially, knowledge is the expertise humans have at doing things, with all of the opinions, experience and wisdom that that implies. Data are simple facts, information is data with context, and knowledge is information with connections. Knowledge implies a course of action. (Davenport and Prusak 1997)

We contend that by consolidating the information process under independent management, we will create knowledge by making unprecedented amounts of reliable project data simple to access and understand. This can be achieved through an integrated hypermedia system. (Bush 1945, McManus and Segner 1991, Doherty 1997). Though information systems can be very complex and sophisticated under the hood, user interfaces must be simple and intuitive. This can be accomplished using current Internet technologies.

To understand the function of the independent Information Manager, it is necessary to look at the nature of information necessary for contemporary construction projects (Miles and Ballard 1997). The new model views production as a continuous flow of materials and/or information, starting at raw material up to the final product (Koskela 1992). Today, information is more than words and drawings. It is also a vast array of digitally encoded real time measurements, images and sounds. It is information in multiple formats

[3] Muda is a Japanese term for the type of waste whose elimination is the essence of lean production.

being generated simultaneously in various quantities by all the project participants as well as by numerous automated devices. It is a process that must be monitored and maintained or the process will break down and valuable resources lost. (Alter 1996).

Conventional construction information is discipline based and somewhat limited in scope. It is frequently time consuming and costly to accumulate and process and has limited direct value to the end product. Its reliability frequently influences processes that follow and how those processes interface with other participants. By the same token, its form influences the efficiency with which it is used and shared. Frequently construction information represents "best estimates" or approximations because accurate data would be either too costly or time consuming to accumulate.

Although the written word, telephone, and face to face meetings still have an important role in the exchange of information, the digital vehicle of today is providing new methods and tools for this exchange. Tools such as computers, networks, wireless LANs, web cams, digital cameras, smart cards, proximity readers, inter/intra/extra-nets and environmental sensors are just a few examples (Negroponte 1995). Again, it is easy to see why it is imperative that each project set standards for the gathering, storage, and sharing of information if the information is to create maximum knowledge.

Information can be used for the overall management of a multi-project program or can be used to empower workmen at the point of use, whether that point of use is at the job site or somewhere else in the world. It can be the tool of general managers or the tool of craftsmen. It can operate equipment and machinery without the presence of man or can be the tool for the orderly resolution of misunderstandings between people.

The trend in lean production[4] is toward vertically integrated enterprises, with information technology being the glue that binds the related concerns. In a series of front-page articles on reinventing the enterprise in the June 15th 1998 issue of InfoWorld, editor Michael Vizard describes the emerging enterprise information model with a familiar auto industry example. He postulates that "only about three companies are eventually going to dominate the worldwide automobile industry, and each of these companies will build its own global network of suppliers and business partners, with the IT departments in each of these companies dictating the standards and practices of all the organizations in the network." (Vizard 1998)

Although construction will never be as vertically integrated as the auto industry, there will be opportunities for us to capitalize on the opportunities that such strategic alliances offer. One of the most difficult concepts for us in describing this model is the issue of its being project oriented verses enterprise oriented. Construction historically creates temporary project oriented enterprises. Although a project oriented information model makes a lot of sense, it does not address the multi-project information needs of each entity. At the same time a company wide information system does not address the multi-company needs of a project. Obviously both types of information needs must be met. Doing this effectively requires a certain amount of coordination and standardization. This direction is typically given by the entity at the top of the vertical enterprise. In the auto industry example this is the assembler. In residential construction it is usually the builder. In industrial and commercial construction it is usually the owner. Unfortunately, just at the time when we need owner organizations to define the information model for construction, most owner organizations are outsourcing their construction management

[4] Lean production is the term, coined in the book "The Machine That Changed the World" by Womack, Jones, and Roos, for the production system pioneered by Toyota, which is succeeding mass production.

operations in an effort to concentrate on their core competencies. Therefore, the need has been created for a new construction professional, the Information Manager.

We are proposing an information management model suited to lean construction whose most important features are transparency and inclusiveness. It is a model that provides a unified project oriented data warehouse that can be mined as needed by all parties to the project. By definition, the "project" has its own identity and its own interest. Project participation is temporal, with very few participants involved for the life of the project. Also, some participants have strategic alliances that remain intact long after the project is complete. The information system must meet all their needs by facilitating multi-project strategic alliances as well as short-term participation. Regardless, the major value comes from looking at the whole value stream (Womack and Jones 1996).

Rapid advances in information technologies both enable the proposed model and give weight to the argument that this data warehouse should be created and maintained by an independent Information Manager. Information technology is not generally among the core competencies of designers and constructors. IT requires specialists that primarily understand information technologies and secondarily understand the building process. Work doesn't "just happen". Work must be caused and to cause work requires both planning and commitment (intent). On the other hand, "data happens" as a byproduct of work or planning and it is the enhancement and management of that data that is at issue. Planning requires realistic and practical knowledge on which to base assumptions. Therefore it stands to reason, that if we capture that data and share it with others, we "add value" at each step of the process (Alter 1996).

The IM will be a professional whose core competency is the management of design and construction information. He will not be responsible for designing, evaluating and inspecting the project. He will not be scheduling, coordinating and negotiating work flow. He can be considered a research librarian that would help all participants with both preparing data for entry into the warehouse and with finding and using information from the warehouse. He would also install and maintain the system that automatically records project data. This might include recording the movement of men and equipment onto and within the site, the movement of material into and out of storage, webcam based progress photos and site specific weather data. He would also maintain organized access to the profusion of external project related information such as codes, standards and regulations. The IM will be able to offer a range of available services depending on the nature and scope of the project. On small projects information will probably be managed remotely and on very large projects the IM will have on site staff and facilities.

SCHEDULE CENTRIC PROJECT MANAGEMENT

The management of the project is "schedule centric", whether we view it in terms of the absolute shortest time to completion such as the "critical path" or as a guideline from which we can select options along which to proceed. In either case, it is central to monitoring the progress of the project at any point in time and to the overall management process (Machado 1995). The schedule not only identifies discrete work activities and workflow, it also identifies all necessary material, labor, equipment and capital (Fischer and Jucker 1996). The schedule is not a device that is developed by management and followed by those performing the work. Rather, it is a constantly changing articulation of intention that is continually being defined and refined by the collaboration of those responsible for performing the work. In the past, we generally viewed the schedule in

terms of absolute "windows" or "time frames" and were generally disappointed when the schedule did not live up to our expectations.

The constantly changing schedule represents nothing more than a framework of intentions. The closer an activity comes to inclusion, the more certain our intentions and the more committed our resources. As illustrated by Figure 1, these flows appear to funnel to the point of inclusion. This funnel can be viewed as a window of certainty, with those flows that are farther away from the point of inclusion being the least certain and those closest being the most certain. Note the parallel between the flow of information and the flow of the project deliverables (work).

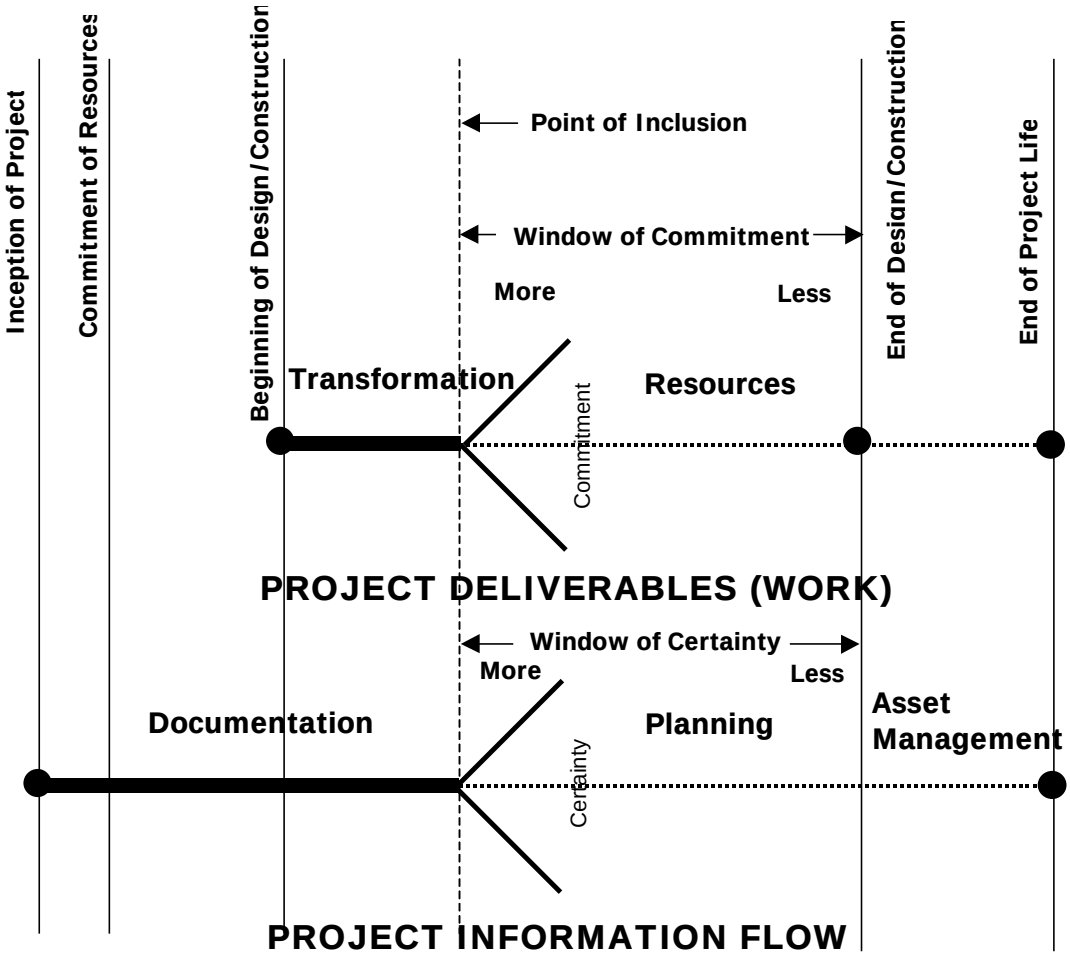

Figure 1: Flow of Work and Information

The need for the various participants to collaborate is evident, with planning being the key ingredient to project success. However, planning itself is not enough. It is just as important to monitor and regulate the flow of resources as they migrate to the point of inclusion. The objective is to have the proper resources arrive at the point of inclusion at the proper time and in the proper amounts. When these flows arrive late the project is

delayed and the schedule extended. When these flows arrive early we build up an inventory of activities waiting to be included which is an inefficient use of resources. Since the flows of resources to the point of inclusion represent a constantly changing "project centric" schedule, we can see that the flow of information is also constantly changing.

The project documents quantitatively and qualitatively identifies materials to be incorporated in the project. This then dictates material, labor, equipment and capital requirements for each activity. When realistically resource loaded, adequate resources will be available at the point of inclusion with minimal waste. Sequencing of activities is the result of experience, expertise and collaboration by the project participants. It is the refinement of this process in the constantly changing schedule that is also the refinement of the windows of certainty and commitment. New information technologies allow for more accurate estimates and simplified planning and resource tracking that is quicker and much more reliable than methods currently being used.

If we view the project schedule as being a series of constantly changing options rather than a fixed work plan, we empower the workmen with more control over their actions. With the project schedule redefined as a sliding scale representation of the interaction of work activities, each participant can view their role with respect to the other participants and understand their impact on the project. We now have enhanced collaboration that is performance based. In the past, the project schedule told workers only what SHOULD be done. It has been the role of on site project management to try to reconcile the SHOULD with CAN. An effective tool being used to accomplish this reconciliation in the schedule, Ballard's Last Planner, provides feed forward information for control by forcing problems to the surface at the planning stage because it assigns work in the right sequence with appropriate resources and is practical. (Ballard 1997). Automated progress reporting technology enhances this approach in that it instantaneously verifies the status of each activity.

LEAN CONSTRUCTION MODEL

Project information is produced in three ways. It is produced by the project participants and shared with other project participants. It consists of either documentation of actions or statements of intent. This first type of information is enterprise based in nature and represents the actions of a single participant. The second type is information produced by collaboration between project participants and is both enterprise and project based in nature. The third type is automatic information that is captured, stored, and processed automatically during operations and is entirely project based. Integration of all three types of information is at the heart of effective project information management. Technology to integrate this into a unified project oriented data warehouse is readily available, dependable and economically feasible. Innovations in database technologies such as data mining and browser based querying allow for fast easy access to this relatively unstructured data.

DATA ACQUISITION

In the same manner that we rethink the lean construction process, we need to rethink the communication and information process that accompanies it. Information, similar to work must also be managed at its lowest level in the value chain. As the producer creates value, the producer also creates information, which belongs to the project. Construction is an

information intensive undertaking. The process, from initial needs analysis to startup and operation, requires numerous entities, each with their own core competencies. Each entity requires substantial amounts of information to perform their job. This information is both created by earlier phases of the project and gathered from outside sources.

Traditional models of information flow are inadequate for lean construction (Howell et al. 1996) each entity only passed on information that was specifically required by contract or, in the best cases, thought to be helpful to downstream processes. Because the sheer volume of data generated was so overwhelming, most was lost. It was thought that clarity required simplicity, hence information was passed on a need to know basis. The problem with this system is that it supposes that each entity fully understands the information needs of all downstream processes. Even worse, it supposes that the drafters of the contracts understand everyone's information needs.

Rather than pushing information directly to specific downstream users, all participants should use project wide information systems or transfer their project-oriented information to the project data warehouse. One way this can be assured is with a contractual requirement that all compensation and dispute resolution be based on official information contained in the warehouse.

In much the same way that the participant creates and provides information related to his core competency, the information manger is able to create knowledge about the project through the use of technology. Technologies such as digital identification (http://www.autoidnews.com/technologies 1998), wireless local area networks (http://www.lantimes.com 1998), local and wide area networks, digital cameras, personal communication devices, mobile computers (http://www.mobilcomputing.com) and environmental sensors (http://www qualimetrics.com) can change the way we view and manage projects. Such devices can gather, process and distribute data automatically with little personal interface. When combined with large capacity databases (http://www2.infostor.com), high-speed processors and high-speed communications (http://www.computertelephony.com), we view the role of the participants from a new transparent perspective. This transparency enhances the project centric orientation of all the participants.

DATA UTILIZATION

In much the same way that Womack describes pulling the product through the manufacturing system as needed (Womack and Jones 1996), information is "pulled" from the information system by the users. Users are now able to access the vast reservoir of accurate and timely information for knowledge needed to plan and execute their work. This information is organized and filtered to exactly meet their needs and is presented in a format that is most beneficial for the task. This reservoir is comprised of data collected from all participants as well as automatic data. The participant can now access the information that he needs when he needs it. Note that this does not minimize the need for collaboration and communication but rather enhances the process because transparency of the system also brings accountability.

There is currently a growing service industry that supplies project oriented information services to construction in the form of project extranets or project specific web sites. A number of these service providers are listed in Table 1. They typically provide password protected organized space on a web server and collaboration tools such as email and threaded discussions.

Table 1: Turnkey Construction Project Extranets

Product	Vendor	Web Site
ProjectCenter	Evolve	Http://www.evolve.com
Firstline	Collaborative Structures	Http://www.costructures.com
ProjectWise	joint venture of Bently and Primavera	Http://www.workplacesystems.com/
e-Builder	MPInteractive	Http://www.e-builder.net/
ProjectNet	Blue-Line/On-Line	Http://www.bluelineonline.com

An IM might use one of these generic services or may provide similar facilities in-house. He would add value by defining uniform information management procedures, setting up parameters for automatic exception reporting, providing training, data entry and querying help, and offering a menu of project documentation services.

"E-Construction" is a logical term for the end to end automation of information flow for the entire construction supply chain. A fully realized system would allow component manufacturers access and input to design documents as they are developed. When approved for fabrication, major facility components would be electronically tagged with codes linked to the design documents and construction schedule. They would be automatically tracked through the procurement process, giving construction planners reliable estimates of feasible delivery dates. At the same time, manufacturers would have access to evolving construction schedules, so that they could time production for just in time delivery. When these components are delivered and installed, the tracking system would automatically update the as-built drawings and the project schedule.

At the job site, last planners, armed with current as-built drawings and reliable information on upcoming material deliveries, would allocate work to their production crews. Each person and major piece of construction equipment would also carry a smart ID. A system of proximity readers would accurately keep track of who and what was where, when and for how long. Planners would then allocate this automatically recorded labor and equipment time to the scheduled work as appropriate, adding the why.

Although the focus of effort is to provide and use only that information that is necessary to convert raw materials into the finished product, a significant amount of incidental information is generated in the process. The resulting comprehensive and accurate information documenting workflow would be invaluable for project management and process improvement. It could also be used for creative compensation algorithms such as basing bonus on planning reliability.

Another significant potential use of incidental information is in the resolution of potential conflicts since all information for the project is stored within the database for the project. If information that is outside the database is not allowed in the resolution of disputes, then the propensity to hoard information is severely diminished.

INFORMATION MANAGEMENT AS A CORE COMPETENCY

Information for a project starts with the inception of the project and follows it throughout the life of the asset. It encompasses much more than the design and construction process alone and, except for the owner, the participants are only interim players in the process. Information, although essential and important to the core competency of each player, has a different relevance with respect to the project as a whole. It is only natural for each

entity to have a somewhat biased view of the project based on their own core competency.

The primary reason that the Information Manager should be included in the project is that his core competency lies in adapting information technology for use by the project participants. He provides the interface between enterprises of different sophistication and size as well as allows for the sharing of IT resources between participants. The IM can gather and dispense more information than would be available by the individual project participants. Perhaps the best reason for the independent Information Manager is that he has no other interest in the project and can provide confidence in the information system and reinforce the integrity of relationships in the project. He establishes the standards and organization for the project as a whole and facilitates the interaction of the participants. He provides the owner tools for the efficient management of the asset and for future projects.

CONCLUSION

It is essential that the concept of independent information management be scrutinized with respect to the principals of lean construction. First we must ask ourselves whether the IM's services creates value, since only the producer creates value. If the IM neither creates nor consumes the information that he manages, can this add value to the process? Can we now define value of the end product in more efficient terms? Next we must look at the value stream. Does the IM contribute to problem solving, information management and the physical transformation task? Does the IM contribute to the flow of the entire process? Does this allow for variable volumes of information to be processed and is the system flexible? Does it contribute to the transparency of the entire process? Does it contribute to the synchronization and alignment of the project and does it contribute to the optimal performance or perfection of the process? We think so. It remains to be measured, tested and proved.

Without question, the need to plan, collaborate and monitor are essential to lean construction. The integration of information tools is at the core of an efficient project. The Information Manager is one of the critical professionals that will make lean construction work. The IM is proficient in current information technologies. He understands the construction process as well as the flow of information. He knows that information management is not project management and has a keen sense of fairness for all participants. He must have no other interest in the project other than the full time management of information for the project. He is the vehicle that makes the work flow.

REFERENCES

Alter, S. (1996). *Information Systems: A Management Perspective*. The Benjamin /Cummings Publishing Company, Inc., Menlo Park, CA.

Ballard, G. (1997). "Lookahead Planning: The Missing Link In Production Control". *Proc. 5th annual IGLC Conference*, Gold Coast, Australia.

Ballard, G. and Howell, G. (1996). "Can Project Controls Do Its Job*?" Proc. 4th annual IGLC Conference*, Birmingham, England.

Bush, V. (1945). "As We May Think", *Atlantic Monthly*, July.

Davenport, T. and Prusak, L. (1977). *Working Knowledge: How Organizations Manage What They Know*. Harvard Business School Press.

Doherty, P. (1997). *Cyberplaces: The Internet Guide for Architects, Engineers & Contractors.* R.S. Means Company, Inc.

Jucker, J. and Fischer, M. (1995). *Modeling and Managing Coordination and Dependence Among Firms Within a Virtual Corporation*. Research report of the Stanford Integrated Manufacturing Association, Stanford Univ., CA.

Howell, G., Miles, R., Fehlig, C., and Ballard, G. (1996). "Beyond Partnering: toward a new approach to project management?" *Proc. 4th Annual IGLC Conference*, Birmingham, England.

Koskela, L. (1992). *Application of the New Production Philosophy to Construction.* Tech. Report, Center for Integrated Facility Engineering, Stanford University, CA.

Machado, R. (1995). "Construction Management according to JIT Philosophy." An article based on an internal paper written in the Production engineering Graduate program, at Federal University of Santa Catarina (Brazil).

Miles, R. and Ballard, G. (1997). "Contracting for Lean Performance: Contracts and the Lean Construction Team". *Proc. 5th annual IGLC Conference*, Gold Coast, Australia.

McManus, B. and Segner, R. (1991). "Hypermedia In Construction Education". *Proc. 27th Annual Conference of the Associated Schools of Construction.*

Negroponte, N. (1995). *Being Digital*. Alfred A. Knopf, Inc., New York.

Womack, J.P., Jones, D.T. (1996). *Lean Thinking.* Simon & Schuster, New York.

Womack, J.P., Jones, D.T. and Roos, D. (1990). *The machine that changed the world*. Rawson Associates, New York.

Vizard, M. (1998). "Are you prepared to face an IT oligarchy?" *Infoworld*, June 15.