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Developing Benchmarks for Construction Information Flows

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Recent research suggests that the efficient movement of information between project stakeholders is a critical factor in the success or failure of a construction project. Unfortunately, little effort has been made to understand which information flows are important, or to understand how quickly critical information components can be processed. This paper identifies key construction information components, and outlines a means for developing benchmarks for specific information flows. Benchmarking is a well-known system that uses a given standard to improve the efficiency of individual processes. Using historical data from recent construction projects, information process cycles were analyzed to develop a benchmark for a single information flow: the construction submittal process. This benchmark can be used to measure and improve the processing speed of a construction submittal package. More importantly, when benchmarking is applied to other critical information flows, this system can be used to improve the efficiency of the construction communication process.

Key Words: Information Systems, Project Management, Information Benchmarking, Information Flow, Information Speed

Background

The design and construction of a building project is an information driven business. From the birth of a project to its final completion, ideas are developed, decisions are made, and thousands of pieces of information are transferred between people and firms. These information flows include the design and technical data, the contractual details, and the management facts needed to administer and control the project. Given the advent of high speed internet communications, these information flows are being transmitted, received, and acted upon in increasingly compressed time frames.

More importantly, research has shown that the smooth and efficient movement of that information is one of the keys to managing successful construction projects. In a recent study by the Construction Industry Institute, the authors note that, "Throughout the entire life cycle of a project, there exists a need to identify, compile, and accurately disseminate relevant information among team members. Project performance can be enhanced through the implementation of effective project communications, and projects can fail if hindered by poor communications" (CII, 1997).

Unfortunately, the process of moving construction information is becoming increasingly complex. In many cases, onerous contracts and growing litigation have made project teams adversaries instead of allies (Pietroforte 1993). Decreasing product life cycles and growing capital costs are compressing the time needed to design and construct complicated facilities. At the same time, increasing technological complexity is shifting project control away from the design and contract team toward specialized subcontractors (Kubal 1995). These market forces have fostered an explosion of information, inundating project managers in a sea of letters, memos, logs, and other project communications (Deloite and Touche, 1996).

While most experts agree that information flow is critical to a construction project's success, little effort has been made to develop benchmarks that describe the time it takes to process individual information components. This paper provides an overview of the benchmarking process, identifies key construction information components, and outlines a means for analyzing specific information flows. Using historical data from recent construction projects, information process cycles were analyzed to develop benchmarks for a single information flow: the construction submittal process. While submittal review and approval is only one function of the construction management process, the methodology outlined here can be used to measure other critical information components. In turn, this information can be used to monitor and improve the efficiency of the vital construction communication process.

Benchmarking Basics

Benchmarking is a method that has been used widely by manufacturing companies to improve their business processes, reduce waste, and increase customer satisfaction. The Xerox organization introduced the concept of benchmarking to American corporations in 1979, and other major companies quickly embraced their techniques. In response to increased competition by the foreign firms, Xerox began collecting data on the best practices of other organizations. When firms apply these practices to their own organizations, they reduce production costs, minimize inventory, and dramatically increase their market share (Patterson, 1996).

The essence of benchmarking is measuring individual processes against a given standard or benchmark. Benchmarks can be developed in several ways: First, internal benchmarks can be developed within organizations, and these measurements can be used to set production standards for individual processes. A second approach is competitive benchmarking, where similar firms share production data on their products or processes. A third approach is collaborative benchmarking, which involves an exchange of information from a consortium of companies.

Benchmarking theory can also be applied to project communications, by measuring the process cycle times of specific information flows. Cycle time can be defined as, "the time required to complete one cycle of an operation" (Womack & Jones, 1996). Cycle time analysis has its roots in modern manufacturing, and the work of Frederick W. Taylor. As early as 1895, Taylor advocated the precise measurement of typical manufacturing processes as a way of determining how much work a person could accomplish in a "full days work" (Taylor, 1895). Taylor's work was revolutionary in that he applied scientific methods to business practice through the precise monitoring of specific events, and Henry Ford later refined the practice during the development of the modern assembly line. Today, cycle time measurement is one of the cornerstones of modern manufacturing practice. This data is used widely in business process re-engineering

(BPR) and in manufacturing quality control as a measure of business performance (Davis, 1995; Hammer, 1993; Naisbett, 1985; Prasad, 1996; Ohno, 1988).

Cycle time thinking can be also be applied to the measurement of the construction communication process. Once critical information components are identified, cycle times can be used to develop averages or benchmarks for specific information flows. In turn, these benchmarks can be used as a basis for measuring and improving the speed of critical project communications.

Construction Information Components

In its broadest sense, information can be defined as the data and messages that are transmitted between people within a communications network. In his book on organizational structure and information technology, Harrington (1991) contends that information can be considered in two ways. The classic "resource" view says that information can be created, transmitted, stored, and received by an organization much like the production components on an assembly line. Like the work on an assembly line, many of these information flows can be measured in terms of time, quantity, and quality.

Much of the information generated during the course of a construction project fits this resource or production based view. For example, once a project moves beyond the design stage, its working drawings, specifications, and budgets remain relatively static for the duration of the project. As such, this information can be used effectively by multiple parties.

Unlike the resource view, the "perception" driven view sees information as more than processed data. Here, information is dynamic and constantly evolving, and is often interpreted differently by different parties. For instance, a change request initiated by the design team may be seen by the owner in terms of cost, while the contractor looks at the same request as a schedule impact. According to Harrington (1991) these varying "perceptions" impact the way people handle information, and these differing perceptions can cause confusion and uncertainty. These informal information flows are much more difficult to measure.

While the resource and perception views provide a theoretical framework for understanding information flows, construction information can be classified more narrowly in terms of three categories: technical information, commercial information, and management and control information (BT, 1995).

- Technical Information: This category includes designs and technical evaluations that describe a building. Examples might include drawings, specifications, details, and design clarifications.

- Commercial Information: includes the contract details, which establish responsibilities for the delivery of a project. Includes delivery schedules, costs, prices, payment schedules, terms and conditions.

- Management and Control Information: includes the project management information needed to control the project and generate reports. This category includes information which is developed by the project manager including: Meeting Minutes, Submittals and Shop Drawings, Change Order Status Log, As-Built Drawings, Requests for Information, Contract Status Log, Safety Information, Daily Logs and Project Schedules.

Because the Management and Control information is used to regulate the construction process, the timely flow of this information often has a direct impact on the duration of a project. For instance, many long lead items require the review and approval of the design team, the construction team, and the owner before they can be fabricated. If the flow of approval information between the parties is interrupted or delayed, then the item's delivery will be postponed accordingly. Individual material delays often result in larger project delays. Requests for information, change order approvals, dispute resolutions, submittal and shop drawing approvals review, payment applications are examples of information flows that can impact the schedule performance of a project.

In addition to timely information, project participants also have specific information needs. Tenah (1986) identified several construction information components, when he researched the information needs of specific construction personnel. His study found a wide array of functions within construction organizations and that “information needs” are often “inextricably linked” to the management responsibilities of each member of the project team. Information includes the timely and relevant facts needed to make decisions about the cost and performance of an individual project. These facts include key information on the cost, duration, procurement status, and performance aspects of the project. Tenah analyzed construction information by analyzing the needs of individual personnel. Hence a company president had a need for project cost and schedule summaries, progress forecasts, financial reports, business development info, and corporate strategic plans, while a project superintendent has a different set of information needs.

Using this original data (1986), the author re-sorted the information needs by information variable. By prioritizing these variables based on their frequency, a schedule of information needs was developed. This prioritized schedule is depicted in table 1.0.

Benchmarking a Specific Information Flow

An example of a specific information component is a project's shop drawing and submittal review process. According to the American Institute of Architects, the purpose of submittals is to "demonstrate... the way the contractor proposes to conform to the information given and expressed in the contract documents" (AIA, 1987). The design team uses the submittal process to ensure that the materials and methods that are proposed by the construction team will meet the quality intent of the design. According to Hinze, "Typically, this is done through the submission of the relevant information for the owner's approval. The information must be sufficiently detailed so that the owner can make an informed decision about the adequacy of the item in question" (Hinze, 1993).

Table 1

Prioritized Schedule of Construction Information Needs, (Adapted from Tenah, 1986)

Information Need	President	VP Finance	VP Operations	VP Administration	Procurement Director	Chief Accountant	Operations Manager	Chief Estimator	Division Engineer	Procurement Manager	Construction Manager	Labor Relations Manage	Project Manager	Project Engineer	Assistant Estimator	Planning & Scheduling	Cost Engineer	Estimator	Purchasing Agent	Accountant	Safety Engineer	Field Engineer	General Superintendent	Superintendent	Foreman	Totals
Project Cost Summaries	1	1	1		1	1	1	1	1	1	1		1	1	1		1	1		1		1				17
Project Schedule Summaries	1		1		1		1	1	1	1	1		1	1	1	1	1	1		1		1				16
Project Progress Forecasts	1		1		1	1	1	1	1	1	1			1	1	1			1	1						14
Contract Documents								1					1	1	1	1	1	1	1		1	1	1	1	1	13
Project Financial Reports	1		1		1	1	1		1	1	1		1	1	1					1						12
Government Regulations		1	1	1	1					1		1									1		1	1	1	10
Detailed Project Budgets					1					1			1				1	1	1	1		1	1	1		10
Procurment Status					1		1	1		1			1	1			1			1		1				9
Union & Labor Agreements		1		1		1						1	1	1							1		1	1		9
Vendor & Sub Lists					1					1	1		1		1				1			1	1			8
Detailed Project Schedules											1			1	1				1			1	1	1	1	8
Safety Regulations				1	1					1											1		1	1	1	7
Construction Forecasts		1	1	1	1		1				1															6
Job Staffing Requirements				1			1		1			1	1										1			6
Field Labor Costs				1		1														1			1	1	1	6
Construction & Engineering Methods								1	1					1	1		1	1								6
Contracts					1					1			1				1		1				1			6
Vendor Performance Reports															1		1	1	1				1	1		6
Subcontract Perfomance Reports															1		1	1	1				1	1		6
Historical Cost /Performance Data															1	1	1	1				1		1		6
Production Reports																1	1					1	1	1	1	6
Value Engineering								1						1	1		1	1								5
Bid Results					1			1		1								1	1							5
Critical Item Status													1	1					1			1	1			5
Project Scopes													1	1		1							1	1		5
Quality Control & Testing Reports														1								1	1	1	1	5
Wage & Tax Regualtions				1								1		1						1						4
Experience Data								1	1						1	1										4
Material Purchase Orders										1									1	1			1			4
Construction Legislation			1				1				1															3
Drawing Status													1	1					1							3
Inovice Approvals										1										1			1			3
Back Charges																				1			1	1		3
Change Orders																				1			1	1		3
Submittals & Shop Drawing Status																						1	1		1	3
Business Development Info	1								1																	2
Volume of Work				1					1																	2
Health & Welfare Information				1																	1					2
Training Programs				1			1																			2

Generally, the specifications outline the submittals required for each project. Submittals packages may include a combination of shop drawings, samples, or product data. These documents take the form of "submittal packages" which are developed by the subcontractor and are then forwarded to contractor and subsequently to the design team for review (Fisk, 1988). Because key building components like elevators, mechanical systems, and electronics cannot be ordered until their individual submittal packages have been reviewed and approved, the submittal process is critical to the timely delivery of materials. Figure 1 illustrates the flow of information during the submittal process (Mincks & Johnson, 1998).

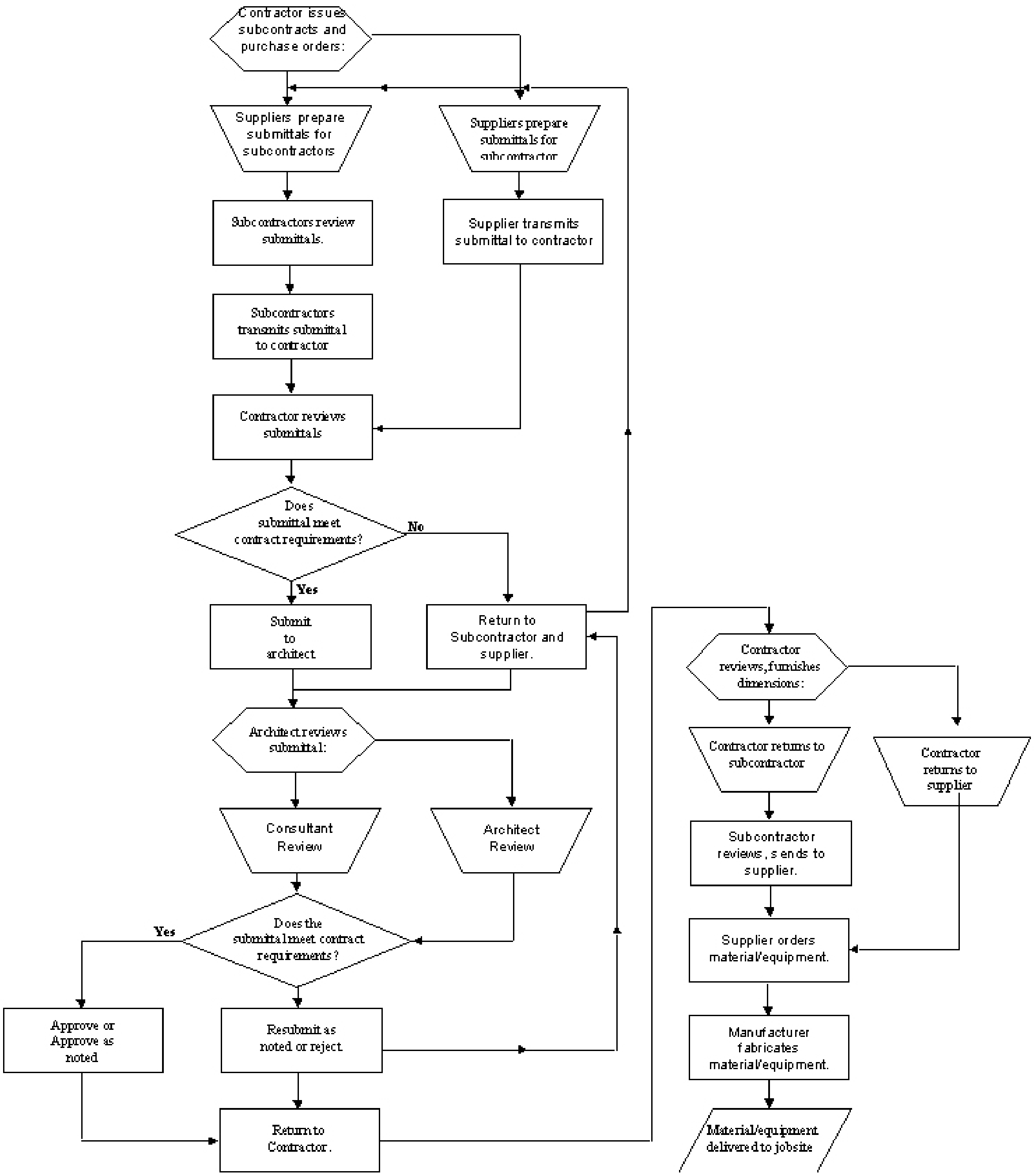

Figure 1. Submittal Process Flow Chart (Mincks & Johnson, 1998)

While other data and information flows can be measured, the submittal process was chosen for several reasons. First, the submittal process requires information transfer and processing between many members of a project team. For instance, a temperature control device submission will be developed by a vendor, submitted to a mechanical subcontractor for review and approval, then submitted to a general contractor for submission and approval. Once approved by the contractor, the submittal is routed through the design team for review approval. When all parties have approved the submission, the information is transferred back through the team members to the originator. If any party rejects the submittal, then the process starts over again. As such, the submittal process is a good example of an information flow that extends through the entire breadth of the project management system.

Secondly, the submittal process is a standard requirement of AIA (American Institute of Architects) contracts. Because most projects in the United States are governed by AIA contracts, the submittal process is well defined. The contract and specifications outline exactly how a piece of information (the submittal) will be generated, transmitted, approved, and re-transmitted. This framework provides an information flow that is standard to most construction projects, and this flow can be measured.

Finally, because submittal review is well defined, project management systems have been established to monitor and control the process. This control device is known as a submittal log, and it tracks key dates during the life of the submittal. For instance, a submittal log will typically note when a submittal is required, and when it was transmitted to approving members of the project team. Given the critical path nature of material approvals, most large-scale construction projects keep detailed submittal logs. Unlike many other construction information components, these logs provide a well-documented record of a specific information flows that are standard to most construction projects. While individual submittals will vary widely from job to job, a statistical analysis of several construction projects can be used to measure the speed of a particular information flow.

Benchmarking the Submittal Process

Submittal data was collected from ten construction contractors that were chosen at random from the register of Associated General Contractors of America. These contractors submitted historical data from 20 projects completed over the last five years. To insure replication these projects met the following criteria:

- Projects were selected from a random sample
- Projects were building construction projects
- Project size was 5 million dollars or larger

After screening, logs from twenty projects were selected and approximately 400 data points were analyzed. An analysis of the total cycle time (calendar days) for each submittal was calculated and recorded. This data was then input into a computer spreadsheet program (Excel). Using Excel's statistical package, the submittal cycle times were analyzed and a mean, mode, and standard deviation were developed for the collected data. Additionally, a confidence interval estimate was made at the 95% level. The mean and mode of the analysis provided an indication of the central tendency of the RFI information cycle, while the standard deviation described the variability of the distribution. According to Babbie, "averages have the advantage of reducing raw data to the most manageable form: a single number that can represent all the detailed data collected" (Babbie, 1990). This single number would provide a statistical benchmark of the time required for a construction organization to process a typical submittal document.

Results

Analysis of the data collected revealed that the average process cycle time for a submittal package was 18.31 days. This number represents the total duration required to process a submittal package, from the day it arrives at a general contractor's office to the day it is re-transmitted to a subcontractor or vendor. The median for the data collected was 16 days, while the mode of the data set, or the value that appeared most frequently, was 13 days. As evidenced by the standard deviation calculation of 10.65 days, the data showed a large range of variability. The data was also skewed to the right. At the high end of the range, a few submittal packages required over seventy days to process, while at the lower end other submittals required only a day for processing. Table 2 provides a summary of descriptive statistics, while figure 2 depicts the frequency distribution of individual submittal cases.

Table 2

Submittal Process Cycles Descriptive Statistics

Mean	18.32
Standard Error	0.534
Median	16
Mode	13
Standard Deviation	10.65
Sample Variance	113.5
Kurtosis	2.75
Skewness	1.26
Range	75
Minimum	1
Maximum	76
Sum	7290
Count	398
Largest (1)	76
Smallest (1)	1
Confidence Level (95.0%)	1.049

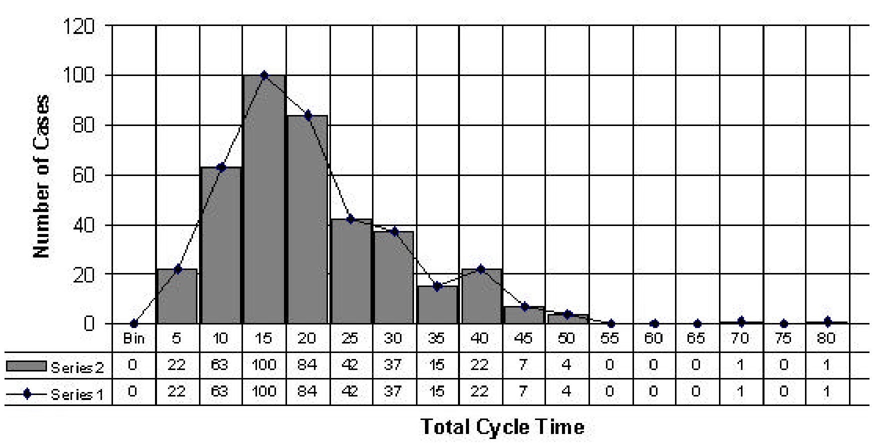

Figure. 2 Submittal Process Frequency Distribution

Some of the variation seen here is the result of the complexity of the submittal packages. Typically a paint sample will require less scrutiny than a concrete reinforcing submittal package. Another reason for the variability may have been the amount of approvals required. As depicted in figure 1.2, the processing of a submittal will often require several approvals including the architect, contractor, engineers and possibly the engineer's consultants. Complex submittals typically require the approval of several sub consultants, while simple submittals require approval by only the contractor and architect.

In developing a significant benchmark, the large standard deviation associated with the submittal data appears problematic; however, a closer look at the data shows that the submittal process cycle means are distributed in a narrow range. Using excel's statistical package, a confidence interval was calculated for the submittal mean using the formula:

$$\bar{x} ? 1.96 \left(\frac{?}{\sqrt{n}} \right)$$

where x is the mean, ? is the standard deviation is the population size, n is the population size and 1.96 equals the area under the normal distribution. At the 95% confidence level, the submittal data has a range of 1.049 days. This suggests that 95% of the means collected from other similar submittal populations would fall between 17.26 days and 19.35 days. The central limit theorem states that "as a sample size (number of observations in each sample) gets "large enough" the sampling distribution of the mean can be approximated by a normal distribution. This is true regardless of the shape of the distribution of the individual values in the population" (Berenson et al. 1988). Given this theorem and the narrow range of the confidence interval (1.049 days), the submittal cycle (18.31 days) appears to be representative of the submittal process for the construction business as a whole. As such, this average provides a statistically significant comparative benchmark.

Conclusions and Recommendations for Further Work

Recent research by the Construction Industry Institute suggests that the efficient movement of information is a critical factor in the success or failure of a construction project. Unfortunately, little effort has been made to understand which information flows are important, or how the flow of information affects the profitability or project performance.

This study identified key construction information flows, and provided a method for developing benchmarks that can be used to measure and improve those flows.

More specifically, this paper analyzed a single information flow: the construction submittal package. Major construction projects typically require 50 - 75 individual submittal packages; each of which must be developed, transmitted and reviewed by several members of the construction team. Because these approvals must be made before materials are released for fabrication, the speed with which submittals are processed can have a significant effect on the critical path of a project. The study determined that it takes over 18 calendar days to approve a typical submittal package.

It should be noted that the benchmark developed here represents only a part of the submittal process. Time is also spent by the vendor or subcontractor in preparing the submittal package and transmitting it to the contractor for approval. While this part of the process was not measured here, anecdotal information collected during this study suggests that this part of the process requires an additional 7 - 10 calendar days. This means that an average submittal package has a total cycle time of almost four weeks.

When applied to other critical components, information benchmarking could help improve productivity, reduce project durations, and improve communication performance.

This study raises questions that may serve as the basis for further research. For instance, do firms that use benchmarking have higher profitability levels than firms that do not? Is there a correlation between information cycle times and profitability or customer satisfaction? What are the information flows that are critical to the timely completion of a construction project? What information problems typically result in project delays? How can other systems can be used to monitor and report on key information flows?

Interestingly, the rapid development of construction information technologies should also help researchers with the development of information process cycles. Currently, several project management programs allow users to automatically track the progress of critical items like requests for information (RFI's) , change order approvals, and payment applications. As such, the process times for individual information components can be easily captured and compared against internal or external benchmarks. Software programs could also be developed to automatically track the distribution of specific information components through a project network.

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