Collecting Constructability Improvement Ideas

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Abstract: Project constructability improvement data collection techniques including voluntary survey, questionnaires, interviews, preconstruction meeting notes, and final project reports are discussed and analyzed in detail. Constructability data collected on a large refinery expansion project solicited with various collection techniques from various project personnel are presented. Considering six major types of constructability improvements, from both quantitative and qualitative points of view, two primary questions are addressed: (1) Which data collection methods are best in soliciting certain types of data; and (2) which source types are the most effective contributors in soliciting certain types of data? Numerous recommendations for effectively collecting constructability improvement data are presented.

Introduction

In this article, constructability improvement data collection techniques are discussed and analyzed. From both quantitative and qualitative points of view two primary questions are addressed:

1. Which data collection methods are best in soliciting certain types of data?
2. Which source types are the most effective contributors in soliciting certain types of data?

The emphasis is not so much on the efficiency of collection efforts as on their effectiveness. That is, the objective is not to determine, e.g., whether data collection methods have a more significant effect on data collection success than does source type; rather, how may the most data be collected?

Collecting Improvement Ideas

Collecting constructability improvement ideas is not an easy task. It requires perseverance on the collector's part and often alternative thought processes for those providing the ideas. Designers are asked to think like constructors and constructors are asked to think like designers. Many different types of people are involved, several different data collection techniques may be used, and a broad range of information is solicited.

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A diverse blend of information sources is necessary for successful data collection. For a construction organization, appropriate participants for a constructability improvement study include craft foremen, general foremen, superintendents, inspectors, field engineers, area coordinators, and project managers. It may also be desirable to involve the craftsmen themselves, as well as safety and warehouse personnel. For a design organization, design engineers, design managers and site engineers should be involved. Owner engineers, site inspectors, and coordinators can also contribute significantly to a constructability program. While not used as data sources for this study, material and equipment vendors should be considered. Technical societies may also provide valuable information. Many different project participants people should be involved and each may be most responsive to a different data collection technique.

The range of techniques available for data collection is also broad. Voluntary surveys, questionnaires, and field interviews are all effective ways of gathering information. Final project reports from previous jobs and construction rework documentation also provide insight into ways project constructability may be improved. These techniques are discussed below.

Likewise, the kinds of data sought are many. Design, procurement, and construction activity improvements can all be a part of the constructability effort. The design may be altered in any of several ways in order to simplify construction. Changes in the methods of communicating engineering information may be desirable. Construction techniques and management policies may be modified to ease the construction effort. Improvements in the way vendor and subcontractor services are delivered should also be investigated.

Data Collection Methods: Voluntary Survey

A voluntary survey is a program in which field project personnel may submit any type of constructability improvement idea at will. While a significant amount of effort is required to administer such a technique, the ideas collected are likely to be generally different from those solicited by questionnaires or interviews. Since this technique is essentially a "suggestion box," the ideas collected are of a type which may be overlooked with the other techniques. Also, since ideas may be submitted at any time, the technique and response environment biases characteristic of questionnaires and interviews should be less significant. Thus, while the voluntary survey technique may not be considered the most effective one, the results may be somewhat unique.

In comparison with the other methods, additional effort is required to administer a voluntary survey. For the project investigated, a significant amount of time was devoted to setting up the survey. Some of the major steps required are listed:

1. The support and enthusiasm of project owner management and constructor management must be enlisted. This support should be communicated down the organizational line in the field.

2. Survey forms must be developed. Simplicity and understandability are most critical.

3. Survey administration procedural flow charts for the distribution, gathering, and review of surveys should be drawn up. These should incorporate as many needs and requirements identified by those involved as is effective. Additional procedural forms may be necessary.

4. Materials for promoting survey awareness should be prepared and circulated. At crew gang-box meetings, presentations should be given and a high level of program publicity should be maintained with newsletter articles, posters, etc. Worthwhile suggestions and the names of the originators should be publicized.

5. Periodic program review meetings should be conducted at various levels to ensure a supported program. Follow-up efforts should be conducted to insure that flow-chart procedures are being correctly followed. Response frequencies should be charted for each craft to identify weak areas.

These steps are necessary for a successful voluntary survey program.

Survey administration procedures should be tailor-fit to the needs of the participants. Some major concerns regarding the review process are listed:

1. All ideas should receive fair consideration.
2. Ideas should be reviewed at the highest level in the field construction organization. Personality conflicts may cause problems if craft superintendents are given authority to reject ideas.
3. Whenever possible, suggested ideas should be implemented on the project.
4. Timely feedback to the source should be provided. Implementation details or reasons for rejection should be reported.
5. Material incentives for participation should be considered, particularly for those ideas which make possible significant savings. A successful joint effort should benefit all participants.

What problems can be expected with this and other data collection tools? Of course, any time constructability problems are solicited, a certain number of personal and petty complaints will surface. Also, and particularly in the construction industry, a great deal of resistance to change exists at all levels. Without effort, this can cause a quick dismissal of ideas which are actually of merit. Problems can also occur when survey administration procedures do not respect the constructor organization chain of command. For this reason, while superintendents may not be given idea rejection authority, their review comments should be solicited. Lastly and importantly, conflicting program goals of those involved should be anticipated. Constructors will tend to use constructability improvements as an excuse to point a finger at designers and vice-versa. For these situations, the owner's role as program coordinator is critical.

Questionnaires

Questionnaires directed to construction and design personnel are also effective methods of gathering constructability improvement ideas. With

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this technique, specific written questions are used to provoke the thoughts of respondents. While, as with the survey, simplicity and brevity are desirable in questionnaire design, it is helpful to give examples of the types of ideas solicited. Appendix 1 outlines the issues to be addressed in designer and constructor questionnaires and those analyzed in this study.

Separate questionnaires should be designed for both constructors and designers. While constructors will generally have had adequate experience to effectively critique the construction-sensitivity of designs, the communication of the design, construction techniques, and management policies, the most significant contribution of designers is the identification of those design information needs which they believe would improve project constructability. The assumption is that designers know what types of information, if available to them, would improve the constructability of their designs. While such information is likely to deal primarily with the design itself and the communication of the design, specific construction techniques and management policies may also be identified as information needs. Questions soliciting preassembly opportunities and other sequencing issues may also be effectively answered by designers.

The primary advantage of the questionnaire is that the thoughts of many people can be collected with a relatively small expenditure of effort. However, such a technique has some disadvantages. Given no oral explanation or discussion of the questionnaire beforehand, the primary problem associated with constructability questionnaires is typically an inadequate understanding of constructability or of the scope of improvements possible. For this reason, questionnaires may be ineffective with foremen and craftsmen. A second problem is the often incomplete or unclear explanation of problems and/or improvements by respondents. For the project investigated, it was not uncommon for one-phrase answers to be given to questions. With more comprehensive explanation and instruction at the beginning of the questionnaires, these problems may be mitigated. Another disadvantage of this technique is that data collectors are given no opportunity to deal with respondents possessing poor attitudes.

On-Site Interviews

A very effective technique for collecting constructability improvement information is the individual on-site interview with construction personnel. While extensive time and effort is required for this technique, the payoff does occur. In comparison with other techniques, ideas of higher quality are gathered from personal interviews. Some of the reasons for this technique's success are listed:

1. Two-way discussion is possible, resulting in fewer misunderstandings.
2. The composition of questions and examples given may be uniquely tailored to fit the source type or work category discussed.

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3. The interviewer is given the opportunity to assess poor attitudes toward the study, and with additional discussion these can usually be reversed.

4. Interviewees are provided with quiet and uninterrupted time in which they can devote their full attention to the questions.

For the project investigated, single-person on-site interviews of 30–45 minute durations were conducted with general foremen, superintendents, field engineers, area coordinators, constructor inspectors, and owner site personnel.

Pre-Construction Meeting

A pre-construction meeting between designers and constructors provides a good opportunity for brain-storming and discussing ideas that improve project constructability. In fact, when constructability improvements have been sought in the past, pre-construction meetings have generally been the method used. It is a straightforward and effective way of identifying some major issues of constructability, such as general accessibility needs, engineering information scheduling, and procurement policies.

While this practice is certainly worthwhile and should be retained, the shortcomings of the pre-construction meeting as a technique for collecting constructability ideas should be realized. Two primary deficiencies of the method are listed:

1. Whenever the meeting is held, it is too late for some ideas to surface or be implemented and too early for others.

2. It is uncommon for intermediate level construction field personnel to attend the meeting; thus those with significant potential for input are not involved.

These drawbacks limit the data collection capability of this method. The designer-constructor pre-construction meeting is a good supplementary technique for collecting constructability information but should not be relied upon as the primary method. Other techniques that are implemented during the construction phase and involve hands-on personnel should be considered.

Final Project Reports

While final reports from past projects were not utilized in this study as a data collection technique (primarily due to the age of those available), they should generally be taken advantage of in this manner. Final project reports avail the opportunity to document the failures and successes of past construction projects, and as such should incorporate comments on constructability problems and solutions. Of course, since the benefit from such reports is directly proportional to the recall abilities of project managers and the amount of preparation effort they expend, for such an effort to be successful, a systematic approach is necessary. To ensure complete documentation, an outline of important construct-

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ability issues tailored to the particular project type should be drawn up and used as a checklist when final reports are written. In this way, data retrieval is also made more efficient and the mistakes of the past may become lessons of the present. From project to project these lessons may be accumulated and, over the years, new approaches toward addressing problems may become standard practices.

Case Study: Refinery Expansion

The constructability improvement data analyzed here were collected over a six-month period between 15 and 35% project completion. The construction project was a five year, 1.1 billion-dollar refinery expansion performed under a cost-reimbursable contract.

With the exception of final project reports, each of the methods discussed above was utilized in identifying constructability improvements.

TABLE 1.—Response to Data Collection Techniques

Collection technique (1)	Number of responses (2)	Percent (3)
Voluntary survey	58	17.3
Questionnaire	92	27.5
Designer	29	8.7
Constructor	63	18.8
Interview	137	40.9
Pre-construction meeting	48	14.3
Total	335	100.0

TABLE 2.—Source-Type Responses to Different Data Collection Methods

	Collection Method Response, as a Percentage			
Data source type (1)	Voluntary survey (2)	Questionnaire (3)	Interview (4)	Total (5)
Constructor				
Inspector	3.4	10.9	17.5	12.5
Area Coordinator	1.1	13.1	13.1	7.0
Superintendent	15.6	17.4	4.4	10.8
Engineer	19.0	7.6	5.1	8.7
General Foreman	3.4	—	32.2	16.0
Foreman	17.2	—	—	3.5
Craftsman	15.6	—	—	3.1
Designer				
Design Supervisor	1.7	13.0	—	4.2
Engineer	3.4	18.5	—	5.9
Owner				
Supervisor	1.7	5.4	4.4	4.2
Inspector	3.4	7.6	12.4	9.1
Engineer	19.0	18.5	10.9	15.0
Total	100.0 (N = 58)	100.0 (N = 92)	100.0 (N = 137)	100.0 (N = 287)

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With some exceptions, constructor and owner site personnel were exposed to all methods. Questionnaires were not directed to general foremen, or craftsmen, but were the only methods used to solicit information from designers. In addition, no foremen or craftsmen were interviewed.

Once collected, nearly 500 ideas were given an in-depth review before further analysis commenced. Inappropriate, marginally beneficial and repeated ideas were screened, resulting in 335 acceptable constructability improvement ideas. Table 1 indicates how these were collected. Quantitatively, the personal interview was the most effective technique for collecting such data. Questionnaires were also effective. Data from past project reports were not used in order to maintain a timeliness of observations and findings.

Table 2 shows the extent to which different data source types responded to the various collection methods. Acknowledging that not all source types were solicited with each method, the most common respondents to the voluntary survey were owner site engineers, constructor field discipline engineers, superintendents, foremen, and craftsmen; all of these responded fairly equally. Owner site engineers, design engineers, and constructor superintendents frequently responded to questionnaires. Interviews were most effective with general foremen. Constructor inspectors, area coordinators, and owner inspectors also appear to have felt comfortable with this technique. Overall, constructor general foremen, inspectors, and superintendents and owner engineers were very responsive to the study.

Relating Data Collection with Improvement Types

A classification system or listing of types of constructability improvements was given in Ref. 1. This list is repeated in Appendix 2. Given that the 335 improvements analyzed were classified accordingly, two questions surface:

1. What types of improvements are generated from the different data collection methods?
2. What types of improvements are generated from the different source types?

Table 3 identifies the type and frequency of constructability improvement ideas generated from the various data collection techniques. In comparing the technique percentages with the overall classification percentages given in Ref. 1, insight is gained into what methods may effectively be used to collect certain types of information. Some findings are listed:

1. The voluntary survey does not appear to be an effective method of identifying needs for constructor input to design.
2. Designer questionnaires are a particularly good method of identifying need for constructor input to design, but are ineffective in identifying construction technique or management policy improvements.
3. Constructor questionnaires are effective in identifying construction technique improvements but appear to be less than effective in critiquing

TABLE 3.—Data Collection Techniques and Associated Improvement Types (%)

Type of improvement (1)	Voluntary survey (2)	Questionnaires		Interviews (5)	Pre-construction meeting (6)
		Designer (3)	Constructor (4)		
Construction-sensitive design	22.4	17.2	27.0	37.2	27.1
Communication of engineering information	20.7	13.8	12.7	21.9	41.6
Construction-originated techniques	24.1	6.9	28.6	17.5	10.4
Resource management policies	22.4	0.0	22.2	17.5	2.1
Procurement practices	10.3	3.4	7.9	4.4	14.6
Constructor input	0.0	58.6	1.6	1.5	4.2
Totals	100.0 (N = 58)	100.0 (N = 29)	100.0 (N = 63)	100.0 (N = 137)	100.0 (N = 48)

the communication of engineering information.

4. The interview is an effective way to identify ways in which designs may become more construction-sensitive.

5. The particular pre-construction meeting analyzed, which may or may not be representative, dealt primarily with engineering information communication and procurement issues. Few construction management policies were addressed.

TABLE 4.—Source Types and Associated Improvement Types (%)

Type of improvement (1)	Engineers (2)	Inspectors (3)	Supervisors (4)	Superintendents (5)	Area coordinator (6)	General foremen (7)	Foremen (8)	Craftsmen (9)
Construction-sensitive design	33.0	24.2	33.3	25.8	45.0	39.1	0.0	0.0
Communication of engineering information	21.6	11.3	8.3	19.4	25.0	28.3	10.0	0.0
Construction-originated construction techniques	10.3	30.6	33.3	25.8	15.0	10.9	40.0	55.6
Construction management policies/standards	9.3	22.6	25.0	29.0	10.0	13.0	50.0	37.3
Procurement practices	8.2	9.7	0.0	0.0	5.0	4.3	0.0	11.1
Construction input to design	17.6	1.6	0.0	0.0	0.0	4.3	0.0	0.0
Totals	100.0 (N = 97)	100.0 (N = 62)	100.0 (N = 12)	100.0 (N = 31)	100.0 (N = 20)	100.0 (N = 46)	100.0 (N = 10)	100.0 (N = 9)

Table 4 identifies the type and frequency of constructability improvement ideas generated from various source types. As before, in comparing the technique percentages with the overall classification percentages (1), insight is gained into what source types may effectively be involved in collecting certain types of information. Some findings are listed:

1. Engineers (including designers) may effectively identify needs for constructor input to design, but are less effective in critiquing construction techniques.
2. Inspectors may effectively critique techniques but are less successful in improving methods of communicating engineering information.
3. Supervisors, superintendents, and foremen are effective in critiquing construction techniques and management policies but may offer little in the way of procurement practice improvements or needs for constructor input to design.
4. Area coordinators and general foremen have no problem identifying design improvements. General foremen are also good sources for ideas improving the communication of engineering information.

Data Quality Analysis: Voluntary Surveys

Table 5 provides additional information on the responsiveness of those participating in the voluntary survey. The number of surveys per source is presented as a measure of willingness to participate. Site engineers and general foremen appear to have ideas and are willing to contribute. A measure of feasibility is also presented. "Feasible" ideas were those ideas reviewed and accepted by project managers as technically and economically feasible on the project investigated or on future projects. Nonfeasible or rejected ideas were judged accordingly for one or more of the following reasons: (1) Not technically feasible; (2) not economically feasible; (3) unnecessary/action already undertaken; (4) reduces operability/maintainability; and (5) introduces safety problems. The group with the highest percentage of feasible ideas was the superintendents. Inspectors submitted the least feasible ideas, which may reflect a limited perspective on constructability issues. The other five groups cluster around the two-thirds feasible mark.

TABLE 5.—Analysis of Voluntary Survey Responses

Position level (1)	Number of surveys (2)	Surveys/person (3)	Percent feasible (4)
Superintendent	6	3.00	83.3
Engineers	25	2.25	60.0
General foremen	16	2.22	68.8
Inspectors	7	1.75	28.6
Area coordinators	3	1.50	66.6
Foremen	17	1.22	58.8
Craftsmen	13	1.07	60.1

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DATA QUALITY ANALYSIS: QUESTIONNAIRES AND INTERVIEWS

Data quality ratings for information gathered with questionnaires or interviews are presented in Table 6. The five-point scale explained in Table 7 is used. Some findings are listed:

1. On average, ideas generated from interviews rather than questionnaires are of a slightly higher quality.
2. The range of quality for ideas generated from questionnaires is broad. Ideas of poor, average, and superior quality were identified with this method.
3. Utilizing questionnaires, constructor engineers and owner supervisors provided ideas of above-average quality. Owner inspectors and constructor area coordinators provided ideas of below-average quality.
4. The range of quality for ideas generated from interviews is relatively narrow, with most ideas being considered average or above average.
5. Utilizing interviews, constructor area coordinators provided ideas

TABLE 6.—Questionnaires and Interviews: Data Quality Analysis

Data source (1)	Data Quality Ratings: Questionnaire (2)	Data Quality Ratings: Interview (3)
Constructor		
Inspector	2.44	3.18
Area coordinator	2.00	4.17
Superintendent	3.20	3.50
Engineer	4.50	3.50
Designer		
Engineer	2.54	—
Owner		
Supervisor	4.33	3.00
Inspector	1.67	3.11
Engineer	3.50	3.00
Average	3.02	3.35

TABLE 7.—Idea Quality Rating Scale

Rating value (1)	Idea quality (2)	Criteria: Cost/schedule savings (3)	Recognition of other considerations (4)	Solution offered (5)	Nature of issue (6)
1	Poor	None	None	None	
2	Below average	Questionable	Little	Inadequate	General and/or political
3	Average	Marginal	Some	Reasonable	
4	Above average	Apparent	Apparent	Creative	Specific and/or technical
5	Superior	Significant	Full	Comprehensive	

of above-average quality. Owner supervisors, engineers, and inspectors provided ideas of average quality.

Data Biases

Invariably, whenever such data are collected, biases occur for various reasons. Such biases should be recognized and the related limitations to the findings should be acknowledged. The primary biases associated with the findings presented here are seen as those that relate to either characteristics of the construction project itself, characteristics of the data collection activity, or characteristics of the constructability idea review process.

These biases are all difficult to measure but project bias is believed to be insignificant due to the size of the project investigated. Data collection bias has been minimized by limiting the number of research personnel to two, by making use of prepared questionnaires and interview guides, and by collecting data over a lengthy period of time. Review process bias has been minimized by utilizing quasi-objective review criteria in performing otherwise subjective evaluations. None of these biases is considered to be serious enough to limit the findings.

Conclusions

The major conclusion of this paper is that the most effective constructability data collection program makes use of many data collection techniques and involves many project participants. Also, in soliciting one of these major types of constructability improvement ideas, different methods and source types will vary in their effectiveness. Specifically, the findings of this paper are numerous and will not be repeated here. Table 8 summarizes how constructability improvement ideas may be effectively collected.

TABLE 8.—Summary of Effective Constructability Data Collection

Type of improvement (1)	Voluntary survey (2)	Questionnaire		Interview (5)	Pre-construction meeting (6)
		Designer (3)	Constructor (4)		
Construction sensitive design	+	+	O-Engineer Supervisor	C-General Foreman Area Constructor O-Engineer	+
Communication of engineering information	C-Engineer	−	C-Superintendent	C-General Foreman principal coordinator	+
Constructor-originated techniques	C-Craftsmen Foremen	−	O-Supervisor	C-Inspector O-Inspector	−
Resource management policies	C-Craftsmen Foremen	−	C-Superintendent	O-Supervisor	−
Procurement practices	C-Craftsmen Engineer	−	−	−	+
Constructor input	−	Design Engineer	−	−	−

Note: − = Ineffective; + = Effective, no particular source type.

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Appendix I.—Questionnaire Questions

Designer Questionnaire

1. What specific additional information related to the topics below would enable you to improve the constructability of your design?
   a. Construction techniques/sequences:
   b. Material/equipment/manpower accessibility considerations:
   c. Material/equipment tolerances needs for field flexibility:
   d. Content/format of engineering information:
   e. Modification to outline specifications:
2. Currently several modules or preassemblies are being fabricated at a near-by yard and then transported to the final position. The overall effect on the job is expected to be lower cost and/or shortened schedule. Such assembly-line benefits are being enjoyed on several modules: piping, pipe racks, duct banks, dressed vessels, manholes, and electric pullboxes.
   Please identify additional elements related to your discipline which potentially may provide such benefits to the job if fabricated in this modular fashion. Comment on the technical feasibility, cost/benefit tradeoffs, and potential problems of fabrication in this fashion.

Constructor Questionnaire

1. Related to the topics below, identify specific ways in which project constructability would be improved by altering the design.
   a. Modify specified construction methods (for example, welded versus bolted connections);
   b. Simplify or combine elements of the project;
   c. Repeat or standardize elements of the project;
   d. Identify needs for realistic tolerances or field flexibility;
   e. Provide for material/equipment/manpower accessibility.
2. Identify specific ways in which the communication of engineering information could be made more effective. Consider the information's clarity, format, content, and availability with respect to scheduling.
3. Identify effective construction techniques which were or could have been utilized on the project, but which have not become standard practice. These may include improved sequences of activities or innovative uses of materials, equipment, or tools.
4. Identify ways in which the management of construction manpower, equipment, and materials can be improved.
5. Identify project elements related to your discipline which have modularization or preassembly potential. Express your feelings on the feasibility, cost/benefit tradeoffs, and potential problems involved.

Appendix II.—Types of Constructability Improvements

Description of Types (1)
Construction-sensitive design
a. Optimal design-originated construction technique
b. Simplification of configuration/combination of elements

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c. Standardization/Repetition of elements
d. Flexibility/Adaptability of elements
e. Accessibility-conscious design

Effective communication of engineering information
a. Information availability
b. Information understandability

Optimal construction-originated construction techniques
a. Improved construction techniques/sequence
b. Improved use of materials/sequences
c. Improved use of equipment or tools

Effective construction resource management policies
a. Manpower
b. Construction materials
c. Equipment/tools
d. Cost/schedule/quality information

Vendor/subcontractor service improvements
a. Material identification/shipping improvements
b. Improved assignment of responsibilities

Construction input to design

Appendix III.—Reference

1. O'Connor, J. T., and Tucker, R. L., "Industrial Project Constructability Improvement," *Journal of Construction Engineering and Management*, ASCE, Vol. 112, No. CO1, Mar., 1986, pp. 69–82.