Quantity Control — The Key Element in Project Control

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Project Control

This paper describes recent developments in quantity control systems as they apply to large and very large design construction projects. It has been increasingly recognized that large construction projects require the use of sophisticated project control systems. As a result, "Project Control" has been the subject of numerous articles in the professional literature. The thrust of this paper, however, is somewhat different from these preceding papers. The underlying theme is that good project control requires a comprehensive quantity information system as a base for the Project Control System. Accurate measures of the amount of work involved in a project are required by *all* of the disciplines involved in design and construction.

Perhaps it is best to start with a definition of project control systems. Burger and Halpin (1) have described project control systems as

> . . . the combination of methods by which an organization plans, operates, and controls its activities in order to meet its goals and objectives, utilizing the resources of time, money, people, equipment, materials, and information.

If we accept this definition, then we must accept the fact that project control is a multi-faceted concept encompassing most, if not all, organizational components of large engineering/construction firms. The strongest unifying element among these project control activities is the physical amount of work which must be accomplished. Computation of durations for construction activities, estimation of cost, purchasing of materials all rely on the quantity of work involved. The individual work elements are the common thread running through the project from preliminary engineering to final completion.

Historical Perspective

The pivotal role of quantity control in an overall project control system is an established concept. Engineering and construction firms have long recognized the need to "quantifying" the work involved in their projects. All too often, however, the work of capturing quantity information has been subject to a fragmented approach.

A fundamental reason for the general inadequacy of present day quantity information systems relates to the growth and complexity of current projects when compared to those of the past. Today it is commonplace for the sheer size of a project to require vast amounts of bulk materials, while its complexity and precision of design require an astounding array of engineered mechanical, piping and electrical equipment. Also, the advent of phased construction or fast tracking procedures is causing a greater reliance on preliminary estimating techniques. It is not at all uncommon for a project to start its construction phase when engineering is only 30% complete. Phased construction coupled with increased size and complexity are posing problems which are too large for present day quantity tracking and forecasting systems.

Another reason for the fragmented approach to quantity control is that different organizational entities within a construction company each require quantity information in different forms. Examples of widely divergent quantity data requirements are many, as may be seen in Figure 1. In response to these differing data requirements, many large constructors find that separate organizational entities are performing separate quantity take-offs and estimates, each take-off for a different reason, in a different format and many times with different results. Aside from the obvious inefficiency of performing multiple quantity take-offs and estimates, another problem is evident. That problem, stated succinctly, is one of "credibility" of the organization with owners and clients. An organization cannot hope to present an estimate based on one set of quantities, a construction schedule based on another, a procurement plan based on a third, and expect to maintain credibility with the owner. However, the requirement for producing multi-formated quantity take-offs is a genuine requirement of any large project. The scheduling engineer *does* require quantity data in a different format from the cost engineer and the expediter in a format which is different from the craft superintendent. A quantity take-off strategy is required which allows a constructor to perform one take-off which satisfies the requirements of all of the various groups who require quantity data. The take-off procedure must:

1. allow take-offs to be easily upgraded as better design definition becomes available.
2. allow take-offs to be performed by a single, specialized group.

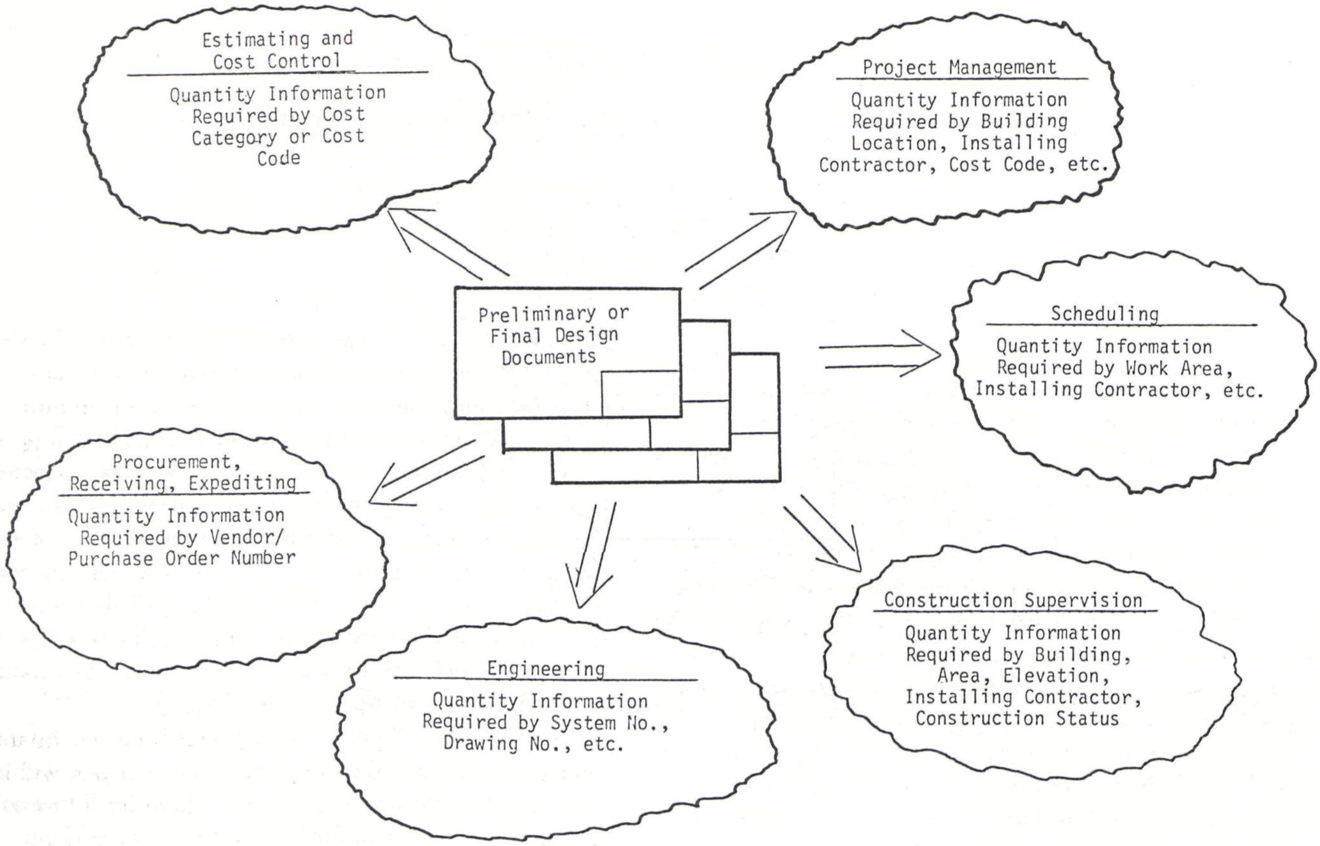

FIGURE 1 — QUANTITY TAKE-OFF FORMATS REQUIRED BY VARIOUS FUNCTIONAL GROUPS

3. allow all organizational entities use and access take-off information in a format which is consistent with their individual purposes.

Centralized Quantity Control and Data Base Managers

One method which satisfies these three criteria is the establishment of a central quantity control organization. The "quantity" group is a staff organization much like the scheduling, cost, procurement or contract administration functions. Utilizing a modern data base managers, the quantity group can take-off or estimate quantity information and redistribute this information to the various functional disciplines and departments.

The data base concept requires that each commodity (i.e. pipe, concrete, structural steel) be broken down to an operational level which may be thought of as its least common denominator. That is, into a level which is consistent with the needs and requirements of each using entity. From this least common level, the commodity can be reconstituted in a variety of formats; each format satisfying the requirements of some functional group. Typically, quantities are subdivided to their installation level. For example, piping quantities would be captured by pipe spool, or pipline numbers. From the pipe spool level, piping quantities which are located in a specified area in a facility may be added together for use by project schedulers or construction supervisors. All pipe spools of a given size, material and schedule may be added together for use by the project cost engineer or project procurement personnel.

Under the data base concept, the quantity group is responsible for determining the individual quantity identifiers, performing take-offs from design drawings (or estimating quantities when design drawings are not yet available) and supplying other ancillary information which they may obtain during the take-off operation. Other project functional groups (i.e. cost control, scheduling, et cetera) are responsible for contributing their specialized information to the centralized data file. The entire procedure, as shown conceptually in Figure 2, yields a centralized quantity file which contains information for both estimated and designed quantities. In addition to providing quantity information, the system becomes a central repository for all manner of project control information. As we shall discuss subsequently, by judiciously selecting the data elements which are contained in the data base, any number of useful reports and summaries may be generated which may be used to support other project control functions.

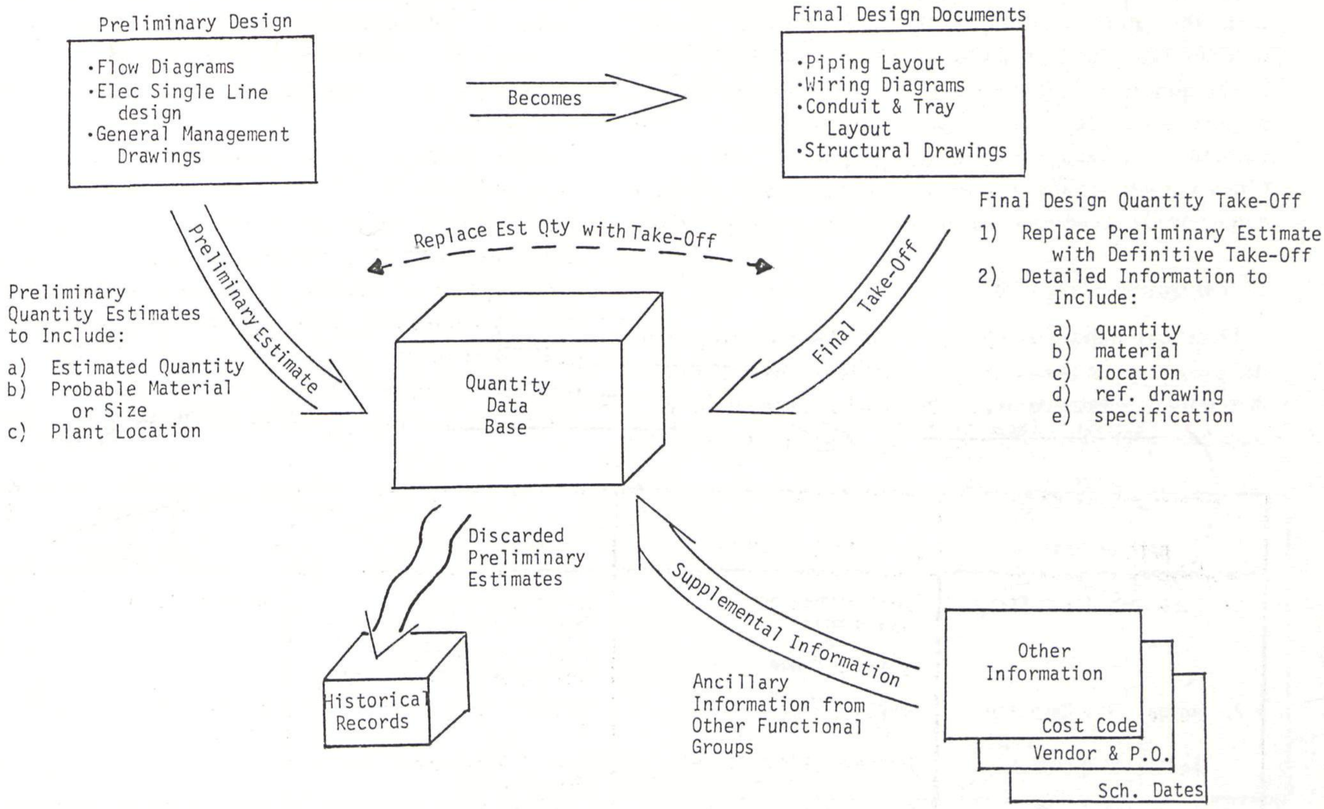

FIGURE 2 – QUANTITY CONTROL WITH THE DATA BASE CONCEPT

The power of the system rests on the concept of including *both* estimated and designed quantities in one central source. Inclusion of both estimated and designed quantities greatly expands the range of applications for which the quantity data base may be used. At the same time, this procedure provides a convenient method of continually updating quantity information as design progresses.

A well conceived system will allow the quantity control group to *estimate* the quantities of work involved from whatever information source is available. For example, original piping quantities may be developed from flow diagrams and equipment location drawings. As design progresses and piping layout drawings, isometric drawings, and finally the manufacturers' spool sheets become

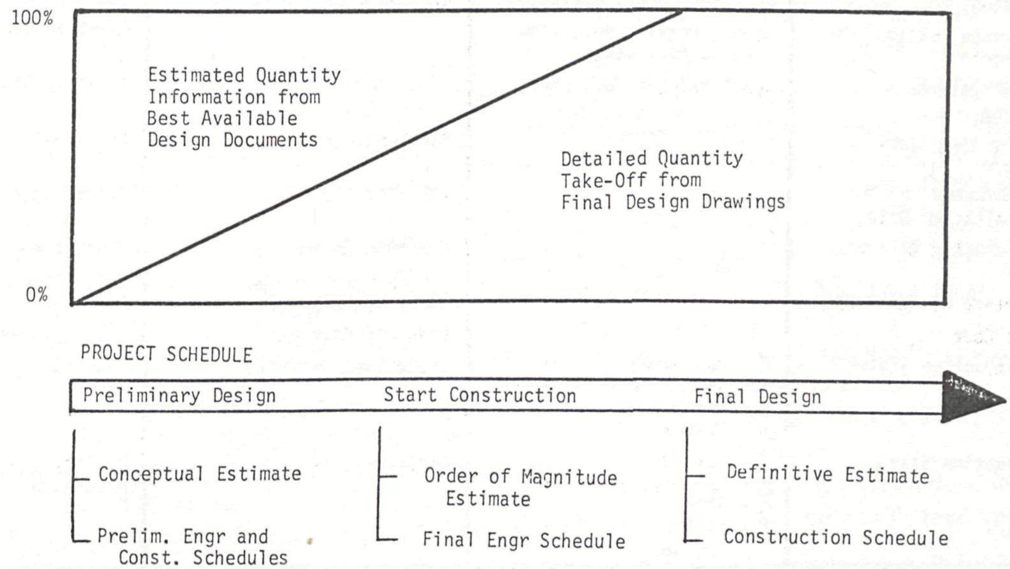

FIGURE 3 – GROWTH OF DETAIL AND ACCURACY OF QUANTITY INFORMATION

available, the original estimated quantities are replaced with the more accurate design information. In this manner, both the accuracy and the level of detail contained in the quantity file increases as the design progresses and as the need for more detailed information becomes evident. This concept is illustrated graphically in Figure 3. Once a quantity data file is developed, data base managers can be used to classify, extract, and present the stored data.

Uses of Quantity Data Files

Data base managers are extremely efficient and powerful tools because they contain versatile report generators. A report generator is a software package which allows a data base user to sort data elements, select particular data elements and summarize information about selected data elements. These three functions — *select, sort* and *summarize* — used with a quantity data base, provide an incredible number of users selected reports; each report tailored to a specific need.

Before considering the typical reports which may be generated using a data base manager, it is necessary to analyze specific data elements contained in a typical quantity control file. As an example, consider Table 1, which contains a list of data elements which may be found in a quantity file for large bore pipe. As may be seen, the pipe quantity data base contains varied and diverse information which imparts the ability to produce many useful documents through the use of the report generator.

DATA ELEMENT	TYPICAL ENTRY	SOURCE DOCUMENT(S)	DEPARTMENT RESPONSIBLE FOR DATA CAPTURE
1. Pipe Line Identifier	Spool Number or Line Number or Estimate Number	Layout Drawing or Manufacturer's Spool Sheet General Arrangement Drawing and Flow Diagrams	Quantity Group
2. Actual Pipe Quantity or Estimated Quantity	Length in Feet Estimate Length in Feet	Layout Drawing or Spool Sheet General Arrangement and Flow Diagrams	Quantity Group
3. Material	Carbon Steel, Stainless Steel, etc.	Available Design Documents	Quantity Group
4. Size & Wall Thickness	4", 6", etc. 40, 80, 40s, etc.	Available Design Documents	Quantity Group
5. Actual Pipe Hanger or Est. No. of Hangers	Actual Count from Design Documents, or Factored Estimate of Hangers Required	Available Design Documents or Historical Estimating Information	Quantity Group
6. Actual Welds or Estimated Welds	Number of Mainline or Branch Line Welds Required or Factored Estimate of Welds Required	Available Design Documents Historical Estimating Information	Quantity Group
7. Location	Building, Area, Elevation	Available Design Documents	Quantity Group
8. Reference Design Documents	Layout Drawing No., Flow Diagram No., etc.		Quantity Group
9. Vendor Reference Drawing	Spool Drawing No., etc.		Quantity Group
10. Vendor Name and P.O. Number		Purchase Order	Procurement
11. Anticipated Installation Date		CPM Schedule	Scheduling
12. Anticipated Delivery Date		Purchase Order	Procurement
13. Start-Up System Number		Start-Up System Definition	Start-Up Group
14. Cost Code		Chart of Accounts	Cost Engineering
15. Construction Status	D - Delivered I - Installed in Hangers W - Welded T - Tested	Production Records	Construction Supervision
16. Inspection Status	P - Passed N - Not Tested H - Hold F - Failed	QA/QC Records	Quality Control/Quality Assurance

TABLE 1 — TYPICAL DATA ELEMENTS FOR A LARGE BORE PIPE QUANTITY FILE

Report Title	Report Structure	Purpose	Used By
Design Completion	Sort and Summarize by Estimated-vs. Designed Quantity within Project Areas	To verify and project design completion	Engineering, Cost Engineering, Engineering Scheduling
Progress Measurement	Sort by Construction Completion Status within Building or Facility	To estimate construction completion for a particular commodity	Cost Engineering, Project Management
Expediting Report	Sort by P.O. Number and Construction Need Dates	To identify critical items or late deliveries	Expediting, Construction Superintendents
Cost Code Sort	Sort and Summarize by Cost Code within Construction Status	To identify completed and remaining work for Cost Reports and Cost Forecasts	Cost Engineering
Building Work Package Report	Sort by Area and Elevation within a Building by Construction Status	To identify the total amount of work and the remaining work by specific work area	Construction Superintendents Project Planners
Start-Up System Report	Sort by Start-Up System within Construction Status	Guide to completeness of individual Start-Up Systems	Start-Up Engineers, Construction Superintendents in the Punch List Stage, Start-Up Schedulers

TABLE 2 — EXAMPLES OF TYPICAL REPORTS

A number of typical reports are lited in Table 2. Table 2 is not meant to be all inclusive, rather it is meant to illustrate the range of applications which may be considered. The flexibility of the report generator allows the information contained in the quantity file to be interfaced either manually or electronically with all other project management control systems.

Applications of Quantity Systems

The range of applications of Quantity Control Systems to project control is limited only by the requirements of the job and the ingenuity of the systems designer. Quantity Control Systems have been designed by various companies for almost every commodity used in construction. Listed below are some of the many construction commodities which have been adapted to the data base concept.

One basic distinction needs to be made in designing a quantity control system, that is, the engineering specificity of commodity involved. That is, some items are designed for a specific function or task while others are items for general or bulk installation. For example, a pump is designed for a specific function within the plant and must be installed at that specific location. On the other hand, a cubic yard of 3000 psi concrete can be used in any location which requires 3000 psi concrete. The specificity of the end use determines the specificity of initial, intermediate and final take-offs. As an approximation, construction materials may be classified into one of three categories:

Commodities Which Have Been Adapted to the Data Base Concept

- Concrete
- Rebar
- Embedded Items
- Structural Steel
- Pipe Large and Small Bore
- Pipe Hangers
- Pipe Welds and Connections
- Valves Large and Small
- Electrical Equipment
- Mechanical Equipment
- Electrical Raceway-Conduit and Tray
- Electrical Cable and Connections
- Instruments (Electrical and Pneumatic)
- Instrument Cable and Tubing

Category	*Example*
Specific use	Mechanical & Electrical Equipment, spooled pipe
Semi specific use	Wire and Cable, instruments reinforc- cing steel, embedded items
Bulk use	Conduit, cable tray, concrete

These distinctions must be accounted for when a quantity capture, forecasting and reporting system is designed.

Summary

The combination of a centralized quantity estimating and take-off group combined with computer data base managers forms a formidable new tool in Project Management. The most sophisticated cost, scheduling, and procurement systems cannot reflect reality without an accurate measure of the work to be accomplished and the work which has been accomplished. The control of the project *scope* is the foundation and project control.

REFERENCES

Burger, Amadeus M. and Halpin, Daniel W., "Data Base Methods for Complex Project Control," Journal of the Construction Division, ASCE, Vol. 103, No. C03.

Style Guide

It is requested that all materials submitted for consideration of publication maintain the following guidelines.

Submit three copies of the manuscript, typed on 8½ x 11 paper, double spaced throughout, with one inch margins. Footnotes should be numbered consecutively and arranged at the end of the manuscript. References should be numbered and listed alphabetically by author at the end of the paper and should follow the form:

3. Wiest, J.D. and F.K. Levy, *A Management Guide to PERT/CPM*, Prenctice Hall, Inc., 1969.
4. Patterson, J.H., "Alternative Methods of Project Scheduling with Limited Resources," *Naval Logistics Quarterly*, December, 1973.

References referred to in the body of the text should be identified by numbers in parentheses, e.g., (1) or (2) p.118. If more than one reference is referred to the following should be used: (2)(16)(25) pp.214–9.

Tables and figures should be numbered in arabic and should be grouped at the end of the manuscript. Within the body of the manuscript indicate the preferred location. If possible, charts, illustrations and tables should be camera ready; all photographs should be black and white, glossy. The author is reminded that all tables, figures, charts, etc. will be printed either 3-1/3 or 7 inches in width; superfluous figures etc. will be excluded at the discretion of the editor.