CIFE
CENTER FOR INTEGRATED FACILITY ENGINEERING

Value-Added Assessment
of
Construction Plans

By

Laurie J. Seibert,
Paul J. Seppanen,
John C. Kunz, and
Boyd C. Paulson

STANFORD UNIVERSITY

If you would like to contact the authors please write to:

c/o CIFE, Civil Engineering,
Stanford University,
Terman Engineering Center
Mail Code: 4020
Stanford, CA 94305-4020

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Title: VALUE-ADDED ASSESSMENT OF CONSTRUCTION PLANS

Authors: Laurie J. Seibert, Paul J. Seppanen, John C. Kunz, and Boyd C. Paulson

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1. Abstract: In the purchase of a constructed facility, the buyer values those components that are in place when the user occupies the building. An activity of placing or assembling such a component is therefore "value-adding." This paper presents a method to classify detailed construction activities as value-adding, contributory or ineffective in order to assess the value-added by individual activities as well as assess the aggregate value-added effectiveness of an overall construction plan. Current approaches to evaluate construction operations are based on limited examples rather than general rules. The proposed method presents a list of nine rules that are applicable to various construction trades. The paper provides examples for the value-adding classification rules, specifies how to decompose activities for value-added analysis, and presents an illustrative test case. The proposed method can assess the overall planned effectiveness of a detailed construction plan or the actual effectiveness of a construction operation. A case study of masonry wall construction indicates that the method requires significant understanding of the construction operation to classify activities properly. The use of this method for construction plan assessment enables a contractor to identify and potentially eliminate or reduce non-value-adding activity in plans as well as predict the overall value-added effectiveness of a plan.

2. **Subject:**

   - **What is the report about in laymen's terms?** Construction plans are composed of activities that may (or may not) do work that is of direct benefit ("value") to the owner. This paper presents a method to classify detailed construction activities as value-adding, contributory or ineffective in order to assess the value-added by individual activities as well as assess the aggregate value-added effectiveness of an overall construction plan.

   - **What are the key ideas or concepts investigated?** construction planning, construction, construction methods, productivity, value-added, construction management

   - **What is the essential message?** It is possible and useful to assess the value to an owner added by individual construction activities in a plan.

3. **Objectives/benefits:**

   - **Why did NSF fund this research?** The concept of value added has provided fundamental insight to the manufacturing industry. This project has the objective of articulating the concept for the AEC industry.

   - **What benefits does the research have to CIFE members?** The use of this method for construction plan assessment enables a contractor to identify and potentially reduce non-value-adding activity in plans as well as predict the overall value-added effectiveness of a plan.

   - **What is the motivation for pursuing the research?** Management can manage only what it can measure. Providing value is a fundamental business objective. The motivation for this research is to develop methods to predict and measure the value being provided by activities

in a plan. The objective is to create measures that allow comparison of the value-added effectiveness of plans in the aggregate and that provide field managerial visibility of opportunities to improve both plans and plan execution.

- **What did the research attempt to prove/disprove or explore?** The research successfully developed and discusses use of a small set of rules that can be used to classify activities as value-adding, contributory or ineffective.

4. **Methodology**: We made videotape recordings of several site construction tasks, identified the detailed activities in the actual construction plans, built a set of nine simple rules to classify detailed activities as value-adding, contributory or ineffective, and discuss the (manual) application of these rules.

5. **Results:**

- **Major findings: The nine value-added classification rules appear useful and general.**

6. **Research Status:**

- **Status:** ongoing

- **Logical next step:** develop computer methods to generate activities in enough detail to enable VA analysis.

- Results are ready to apply by contractors and construction managers;

- **Enabling effort:** Automated detailed activity generation will facilitate VA analysis

VALUE-ADDED ASSESSMENT OF CONSTRUCTION PLANS

by Laurie J. Seibert, Paul J. Seppanen, John C. Kunz, and Boyd C. Paulson

I.   INTRODUCTION

In his book, *Competitive Advantage*, Michael E. Porter states, "In competitive terms, value is the amount buyers are willing to pay for what a firm provides them." In the purchase of a constructed facility, the buyer, or owner, values those components that are in place when the owner occupies the building. The activities necessary to place these components are therefore "value-adding" (VA) in the owner's perspective. This paper presents a methodology for how to elaborate the detail of a plan to a level of detail that is appropriate for assessing the value-added of each activity. Second, it presents a set of rules that project managers can use to classify individual activities as value-adding, contributory and ineffective.

Following this plan elaboration method and classification procedure, a manager can identify specific activities and attempt to reengineer to either eliminate or at least perform non-value-adding activities less frequently. If contractors can reduce the frequency of such non-value-adding activities, the effectiveness of the plan for the owner will be improved.

Value-adding activities are only part of the work completed during a construction operation; any careful observer of a construction site will see both "contributory" and "ineffective" activity that does not directly add value for an owner. Maximizing the fraction of all activities that are value-adding increases the overall effectiveness in adding value during a construction operation. However, to maximize value-added effectiveness systematically, it is necessary to measure the effectiveness of alternative construction methods and plans. Such an analysis method – one that is applicable to a diverse set of construction projects – is not yet in use in either research or practice. This paper proposes a method that classifies detailed construction activities as being "value adding," contributory or ineffective..

Construction plans can be represented as a master schedule or a detailed schedule. Even a detailed CPM (critical path method) schedule usually does not indicate all the activities that compose a construction task, but only shows the major activities themselves. For example, the activity "build concrete column formwork" does not indicate activities such as "drill hole for form tie."

The value-added planning (VAP) method requires decomposition of aggregate high-level activities into individual detailed activities that are solely value-adding, contributory or ineffective. Current CPM schedules generally include high-level activities that include some value-adding and some non-value-adding activities.

A manager or investigator can use the proposed value analysis technique to evaluate actual construction operations as well as construction plans. Videos can provide the detailed time-based records of previous construction that operational analysis requires. By operational analysis, a contractor can compare planned and actual value-added effectiveness, just as contractors now compare budget with costs.

II.   BACKGROUND

Planned effectiveness (boldface identifies terms defined in this paper) is the estimated aggregate value productivity of a construction plan. We define a measure of value-added effectiveness. This measure will be most useful when comparing multiple plans for constructing the same facility component. **Actual**

effectiveness is the actual value productivity of the planned construction method when applied, as compared to the planned effectiveness. An earth moving operation that employed wheelbarrows, instead of trucks, is a low planned effectiveness method. Likewise, a construction method can be highly effective yet be performed inefficiently, resulting in lower actual effectiveness. For instance, the best suited construction method could be chosen for an operation, yet low efficiency and effectiveness will result if the method is employed with delays or poor utilization of resources.

Currently, contractors manage time and costs – not the amount of value being added. As a result, time and cost are the evaluation factors most often used in practice to evaluate the effectiveness of construction plans. These factors indicate particular measures of effectiveness of the overall construction plan, but they do not highlight particular areas of ineffectiveness where improvements could be made either on an individual job or over time in the business. We argue that contractors can measure and manage the value added for the building owner of very detailed construction activities. The focus on value allows contractors to measure and manage the most fundamental component of their business and to identify and implement the very detailed changes that are the basis for continuous business process improvement. The focus on value encourages contractors to identify and compare alternative construction methods, to choose those that are most effective. In addition, this new focus may stimulate contractors to innovate and develop more effective construction methods and optimize resource use.
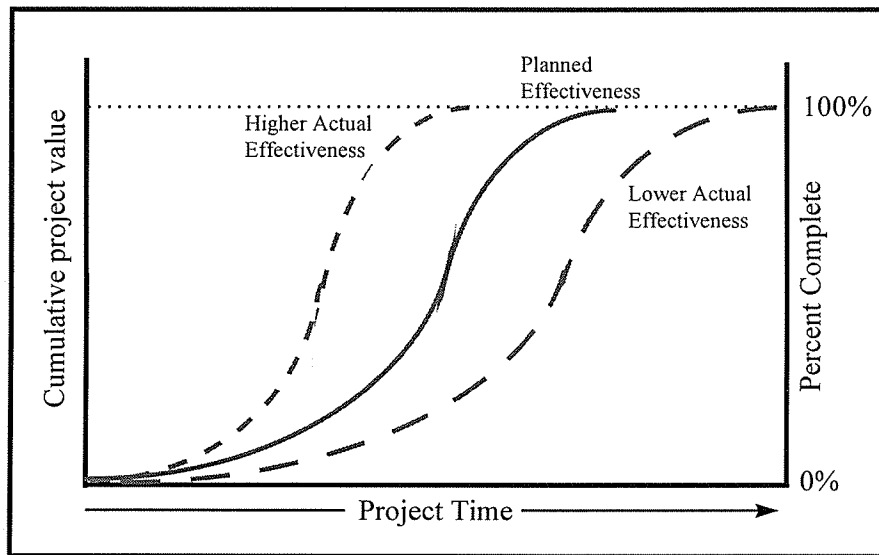

Figure 1: Planned and Actual rates of adding value to a project. From the perspective of an owner, construction adds value to a project at a certain rate. Improving value added effectiveness allows delivering value faster to a project and, potentially, at lower cost.

Figure 1 shows a simplified graph of the amount of value added during construction operations according to time. The solid line shows planned VA effectiveness, while the dotted lines show higher and lower possible outcomes as efficiency affects the planned operation. By considering both the effectiveness of a construction plan and the efficiency of its execution, a contractor could manage operations by objectively measuring VA efficiency during construction operations in comparison to the planned VA effectiveness. While these curves are similar in shape to construction cost "S" curves, as used in this diagram the curves represent the cumulative amount of value added during the project.

III. GOALS

The goals of this report are to define a concept of value analysis in the construction industry, propose classification rules, and present initial validation of the concept in actual construction projects.

IV.   METHODOLOGY

The output of the VA method is a numerical measure of a contractor's effectiveness and efficiency in meeting a customer's needs in the construction of a specified facility. The method classifies each construction activity as value-adding, contributory or ineffective, so the method provides very detailed visibility of the sources of ineffectiveness in aggregate plans.

Value-adding activities are those that add a permanent component to, or prefabricate a permanent component of the owner specified facility. Arbitrarily, we give a VA effectiveness factor (VAEF) of 1 to value-adding activities. Contributory activities are necessary for the execution of value-adding activities, but do not directly add value for the owner. For example, using current methods, formwork must be constructed for a concrete beam to be cast. We arbitrarily give a VAEF of 0.5 to contributory activities in order to recognize the necessity of these activities in construction. Ineffective activities do not contribute to the final product and we arbitrarily give them a VAEF of 0. Averaging the factors assigned to each activity with respect to time results in the overall value-adding effectiveness factor (VAEF) for the construction operation. Theoretically, the VAEF can vary from 0 to 1.0. Most construction operations will fall in the range of 0.25 to 0.75, because construction operations normally involve some contributory and ineffective work.

In order to facilitate comparison of data from various construction projects and researchers, a uniform classification technique must be created for objective evaluation. This method must be not only precise to ensure consistent results, but also flexible to allow its application in diverse construction operations.
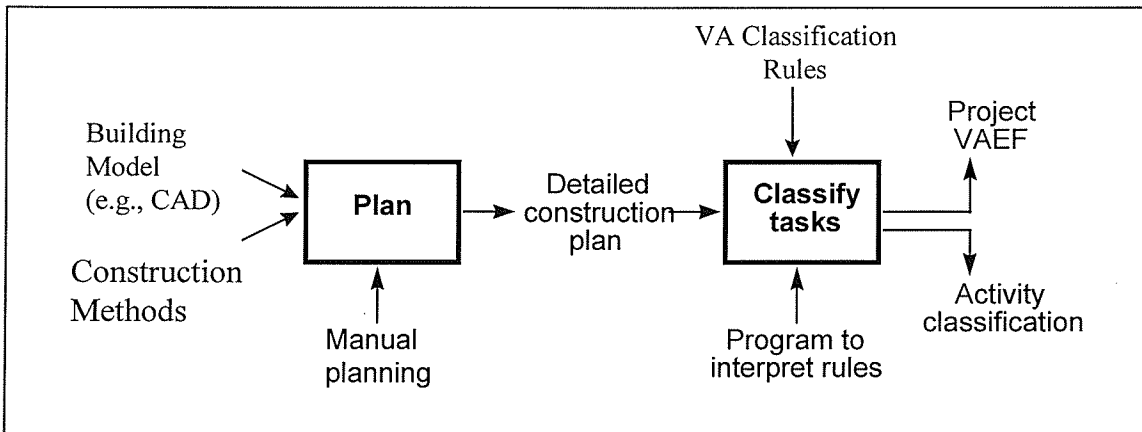

Figure 2: Information Flow in analysis of Value Added of a project plan. The Value Adding classification process analyzes a detailed construction plan and reports both the VA classification of each planned detailed activity and an aggregate Project VA effectiveness factor (VAEF).

We created a simple set of VA classification rules to enable planners to classify activities consistently with respect to value-added (See Section VII). Figure 2 shows the information flow and interpretation that occurs between different stages of the design and construction planning process. An engineer uses information generated during architectural and engineering design to create a CAD model. The CAD model and selected construction methods form the basis for the creation of a detailed construction plan. A person could manually develop the detailed plan but ideally a computer application will create the plan because of the large number of activities required for VA classification. Classified activities and their durations enable VA effectiveness analysis to produce an aggregate VA effectiveness factor for a plan and a list of activities that do not directly add value that the project manager can try to reduce or eliminate.

V.   VIGNETTE: ACTIVITY - BUILD CONCRETE COLUMN

A simple example demonstrating the need for a standard methodology is the construction of a concrete column. The value added by each activity in this construction operation could be different depending on who classifies the activities: owner, contractor, or layman.

The construction of a concrete column involves the fabrication of formwork and reinforcing steel, the placement of concrete, the subsequent stripping of forms, and all minor associated activities. Activities considered in this discussion are prefabricate rebar cage, place concrete, drill hole for form tie, bring the power supply to the workface, review construction plans, sweep the construction work area, and idleness.

The facility owner values only activities that add components to the final structure; for example, prefabricate reinforcing steel, and place concrete. The owner finds no value in these activities: drill hole for form tie, bring the power supply to the workface, review construction plans, sweep the construction work area, and idleness. Though necessary for the construction of the column, drill hole for form tie, bring the power supply to the workface, and review construction plans do not add a permanent component to the structure. Furthermore, the owner finds sweep the construction area and idleness unnecessary to the construction of the column.

In contrast to the owner's viewpoint, a contractor typically equates value with the cost to complete a project. As a result, the contractor may consider more activities to be value-adding than the owner. Therefore, the contractor regards the following activities as value-adding: prefabricating reinforcing steel, placing concrete, fabricating concrete formwork, bringing the power supply to the workface, reviewing construction plans, sweeping the construction work area Even rework and clean-up might be considered value-adding activities by the contractor because they are a normal part of construction operations.
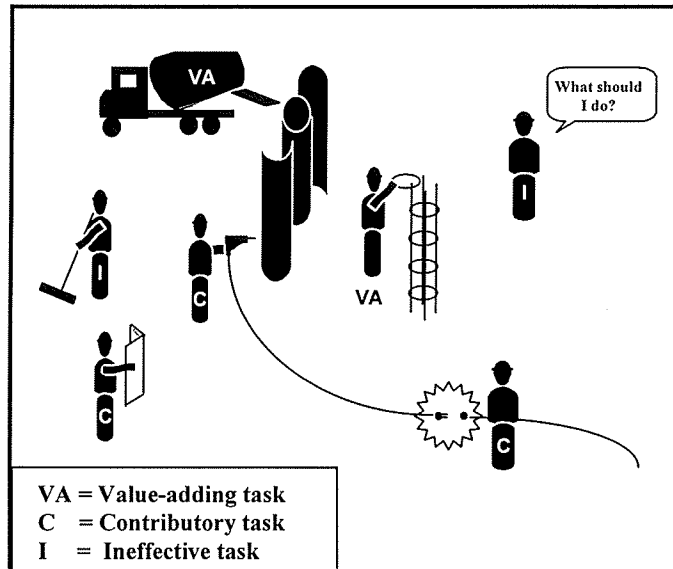
Figure 3: Simple case example. In creating a concrete column, some activities are VA from the perspective of the owner; others are contributory; others are ineffective.

Figure 3 shows the classification of specific activities in the construction of a concrete column, according to the proposed owner-perspective VA classifications. Value-adding activities include prefabricating reinforcing steel and placing concrete. Contributory activities include fabricating concrete formwork and bringing the power supply to the workface. Ineffective activities are sweeping the work area, and idleness.

VI.   PAST RESEARCH

Clarkson Oglesby of Stanford University and by H. Randolph Thomas of Pennsylvania State University conducted research in operational analysis. Oglesby classifies activities into three groups: effective work, essential contributory work, and ineffective work [Oglesby]. Oglesby's method of classification uses examples rather than flexible rules and defines formwork construction and material cutting as effective. Oglesby considers clean-up contributory. The method uses a weighted average to calculate a summary figure, the labor utilization factor (LUF), by giving the effective work a 1.0 weight and contributory work 0.25 weight. Classifications assume the contractor's point of view, that is if an activity has a cost code associated with it, it is effective work.

Thomas uses 10 rules that are specific to placing reinforcing steel to categorize activities into three classifications similar to Oglesby's [Thomas]. These rules do not address formwork and they classify material cutting as contributory. The paper specifies no point of view, yet orients more toward the owner's viewpoint on value than Oglesby's paper. Thomas' classification rules are not general enough to cover all activities involved with building construction, since Thomas analyzed a reinforcing steel placement crew. Thomas' method calculates LUF the same way as Oglesby, but uses a 0.5 factor for contributory work.

	VAEF METHOD	THOMAS	OGLESBY
Task	**Classification**	**Classification**	**Classification**
Fabricate rebar cage	Value-adding	Effective	Effective
Pour concrete	Value-adding	Effective	Effective
Drill hole for form tie	Contributory	?	Effective
Hook-up power	Contributory	Contributory	Contributory
Read plans	Contributory	Contributory	?
Sweep	Ineffective	?	?
Idle	Ineffective	Ineffective	Ineffective

Table 1: Comparison of the VAEF Method and Previous methods of assessing effectiveness of construction activities. The VAEF method offers both generality for different types of construction and specific guidelines that can be applied by construction planners, workers and managers.

Superficially, the VAEF achieves the same results as Thomas's and Oglesby's methods, with minor differences. While Thomas' method refers to specific activities, it cannot be easily applied to other trades because it lacks generality. Oglesby's method is more general, but does not specify the necessary level of detail required.   Table 1 demonstrates the differences among the three methods of classifying the activities illustrated in Figure 3, construction of concrete column. Question marks represent areas of ambiguity within the classification method. As the Thomas method does not provide general rules, ambiguity in the classification of formwork fabrication and clean-up results. Oglesby's more general rules however are unclear in the classification of obtaining information and clean-up.

While our classification method recognizes contributory activity, the traditional manufacturing-based methodology for value-added analysis uses only two classifications: value-added and non-value-added. (Reference will be added later)   While this traditional method is appropriate for manufacturing and is widely used in process analysis, construction operations can be analyzed more accurately using the three classifications of the VAEF method. Because construction projects are built in place and without significant repetition, construction requires a higher fraction of contributory activities than typical manufacturing operations.   Manufacturing operations have the advantage of performing the same activities repeatedly in the same location, allowing engineers to reduce the transportation of resources, time spent obtaining information, and amount of temporary set-up. These are all contributory activities prevalent in construction operations.   In order to better represent the effectiveness of building contractors, VAP gives a weighting to contributory activities as well.

This paper expands and refines the work of past researchers by attempting to create completeness and provide applicability for the construction industry. Furthermore, this paper improves upon past researchers' lack of clarity by providing a rule for the most detailed level of activity decomposition. The generalized rules presented in this research more explicitly define the classification of activities for industry application than the examples presented in past research. Examples of the nine classification rules and a test case provide guidance in the application of this method.

The OARPLAN paper [Darwiche] presents the technique of representing construction activities in the form of object, action, and resource (OAR) along with an automatic construction planner. Both the OAR representation and the possibility of automatic construction planning are relevant to the VAEF method. The observer collects VAEF data in the OAR format. Table 2, for example, lists the object, action, and resources of a group of activities.

VII.   TECHNIQUE

The flow chart in Figure 4 illustrates a methodology to decompose a construction task into appropriate activities and classify each activity as value-adding, contributory, or ineffective. The chart has nine decision nodes. The rule at each node will classify an activity specifically into the corresponding outcome node if it meets the decision node's criteria. If the activity does not fit the criteria, it is passed down to the next decision node and reconsidered. An activity that reaches the ninth decision node is forced into the ineffective outcome node.

The value-added assessment technique enables different engineers to consistently classify the same activities. In current practice no rules exist. Therefore, different engineers can come to different conclusions about the value-added effectiveness of a given operation. For example, a class group project to evaluate a construction operation using Oglesby's technique resulted in widely varying results. Specifically, one student felt that she should classify training as effective work, because she felt the operation could not be performed without it. However, an owner sees no value in employee training because training does not physically contribute to the facility. The owner would rather that employees arrived at the jobsite with prior training. The value-added assessment technique directly addresses training and classifies it as ineffective. The technique attempts to eliminate all such areas of ambiguity.

TASK

Examples		Classification

Examples

TASK

Classification

Place brick on mortar bed
Lower rebar into final position in structure

1. Move permanent object to final position — Yes

No

Assemble boiler unit for power plant installation
Wire piece of reinforcing steel in place for slab
Weld steel girder to column

2. Combine or assemble sub-components of a permanent object — Yes

No

Trowel concrete slab
Sand wallboard joint

3. Perform finish work to specified tolerances — Yes

Value Adding

No

Erect scaffold
Cut steel stud to length
Pick-up trowel before buttering CMU block

4. Perform constructive action on permanent /contributory object or resource for VA or C task — Yes

No

Carry concrete block from material storage to workface
Lift steel from delivery truck to laydown area

5. Transport object or resource toward workface. — Yes

Contributory

No

Check plans for position of steel girder
Find next task to perform on construction plan

6. Obtain information — Yes

No

Move concrete block toward wall for buttering
Place bundle of shingles on roof

7. Move object in workface other than to its final position — Yes

No

Scrape excess paint from window panes
Drill hole at incorrect location
Pick-up or set-down trowel without using it.

8. Clean-up, errors, training — Yes

Ineffective

No

Walk away from workface empty-handed
Wait for concrete delivery to arrive

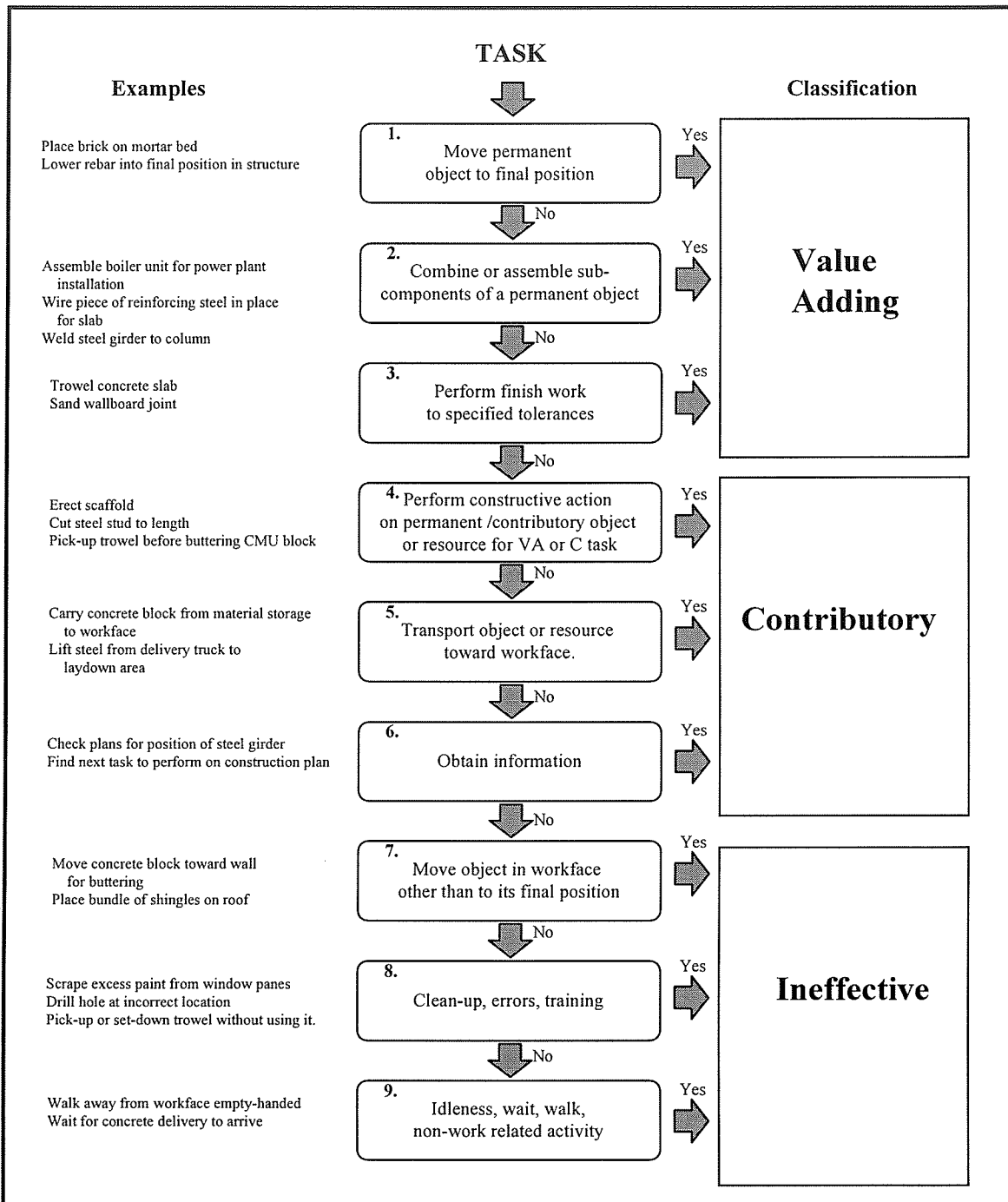**9.** Idleness, wait, walk, non-work related activity — Yes

Figure 4: Precedence of VA Classification Rules: Rules are applied in sequence; once a rule is found to apply to a detailed activity, the activity is given a VA classification, and no further rules are considered.

The flow chart in Figure 4 illustrates a methodology to decompose a construction activity into appropriate activities and classifying each activity as value-adding, contributory or ineffective, according to the rule list. The chart has nine decision nodes that classify an activity specifically into the corresponding outcome node if it meets the decision node's criteria. If the activity does not fit the criteria, it is passed down to the next decision node and reconsidered. An activity that reaches the ninth

decision node is forced into the ineffective outcome node. The nine rules depend on the location of that activity in the work area.
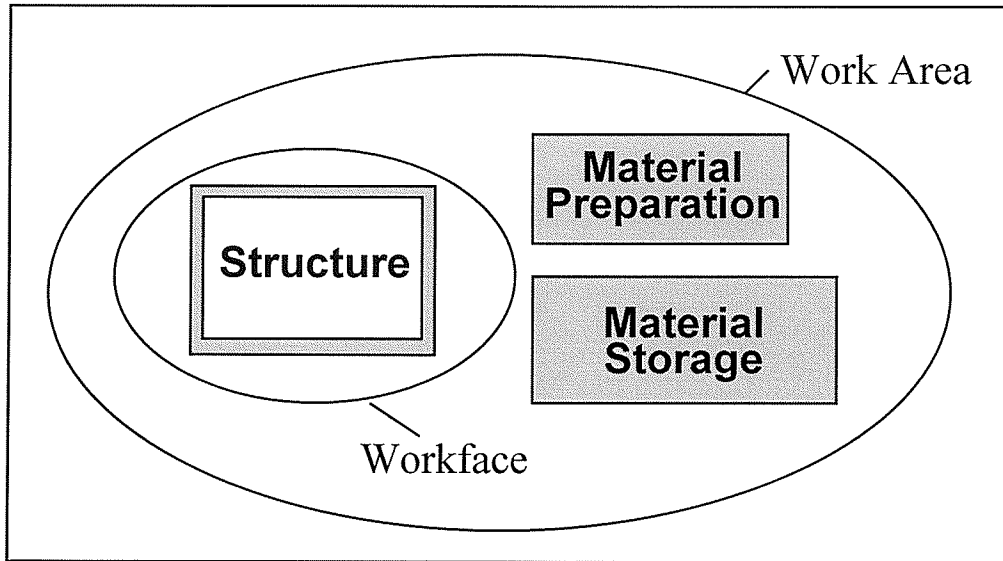

Figure 5: Representative work area diagram. The VA classification rules require identifying the workface and support areas.

Figure 5 represents a simple version of a work area for the construction of a small concrete block enclosure. The structure or structure component, the workface, material preparation, and material storage are located within a work area on the construction site. The work area may move during the construction operation. Reasonable distances, rather than strict dimensions, define boundaries.
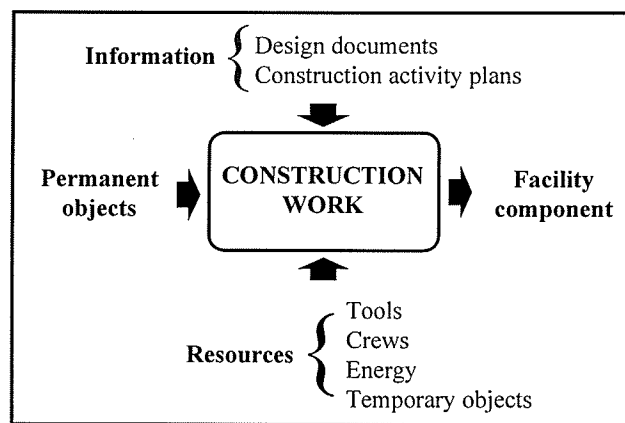

Figure 6: Construction Process Model. From the perspective of an owner, the value-adding function of construction is to place objects into a facility. Any activity that places objects into a facility is value adding; other activity is either contributory (i.e., not value adding but still necessary given a particular construction method) or ineffective.

Figure 6 summarizes the process of construction from the perspective of value added to an owner. Inputs are objects that will become part of the facility, e.g., bricks and pumps. The product, or output, o the construction process is the facility and its components. Construction involves resources to do the construction, but they do not remain as part of the permanent structure. Some resources will be usable for subsequent jobs, such as crews and tools; others may be discarded, such as certain formwork. Information guides and controls the construction process. The VA classification rules consider the value

to the owner of work done on permanent objects by individual activities found in construction activity plans.

VIII.   RATIONALE FOR VA CLASSIFICATION RULES

This section describes those rules that require elaboration and presents the rationale used in developing the rules that significantly differ from past work. We developed the VA classification rules by considering videos made of several construction jobs and also considering the classifications presented by researchers in past research. In all cases, we focused carefully on value provided to the owner. The classification rules of Figure 4 replace the examples presented in previous research.

A.   Constructive Actions

Rule #4 requires the engineer to determine whether or not an action is constructive. A **constructive action** prepares a permanent object, contributory object, or resource for another contributory or value-adding task. For example, a worker measures a steel stud, preparing to cut it to length. Measuring is a constructive action because it prepares the stud for another contributory task. Cutting prepares the stud for the value-adding activity of installation and is therefore also a constructive action.

B.   Errors and Rework

Rule #8 addresses incorrectly completed activities. The incorrectly completed activities, errors, and the removal of the incorrectly completed components are first classified as ineffective work. Then all work necessary to install or fabricate the permanent object or component correctly, including repair and repetition of the task, are classified according to the VA effectiveness rules.

According to the definition of value-adding work, only those activities that add a permanent object to, or prefabricate a permanent component of, the specified facility can be considered as adding value for the owner. Therefore, the rules recognize the value-adding effectiveness of correctly performed work, rather than the possible effectiveness of the activities performed during the incorrectly completed work. Although the worker might perform the same activities more quickly during rework because of the learning curve, a time-based average still reduces the efficiency of the construction operation since the method classifies initial incorrect work as ineffective in the overall VAEF calculation.

C.   Classifying Movement Around the Work Area

Activities involving movement of resources and personnel around the work area are difficult to classify. Four rules consider movement: rule #1, move an object to its final position; rule #5, transport objects towards the workface; rule #7, move an object in the workface other than to its final position; and rule #9, walk. Classification of activities involved with transportation and movement are dependent on whether the worker moves the object or resource within the work area or the workface. The rules are applied in sequence, so when an activity related to walking or transportation requires classification, one must simply go through the rules and choose the first one that is appropriate.

Rule #1 includes an activity such as pick a brick off a temporary pile in the workface and place it in its final position in a wall. This transportation distance is very short, as the workface is a small area that contains the short-term activities involved with the work.

Rule #5 includes all moves that bring material closer to the workface. Activities that move improperly stored material out of the way of work generally do not fit into this rule because these activities do not bring the material closer to the workface. This rule addresses the issue of work flow from storage areas to material preparation areas, and finally to the workface. Each move must bring the material closer to the workface for this work flow, and all the activities involved, to be considered contributory. Therefore the layout of the work area must place the material preparation area between the storage area and the workface. Rule #5 does not include walking empty handed, for example, to return to the workface after transporting something.

Rule #7 classifies all moves within the workface that do not move an object to its final position as ineffective. This rule constrains the size of the workface by forcing the observer to limit the boundaries to a reasonable size, allowing all moves to be classified as either value adding or contributory.

Rule #9 classifies all other walking as ineffective. Any transportation related activity that does not meet the criteria of one of the three previously described rules will be classified as ineffective. Activities included are walking empty handed or carrying a resource away from the workface.

These four rules simplify the classification of transportation. They eliminate the need to recognize some moves as unnecessary, or to know the handling history of an object or resource that the worker moves. If the application of the rules required the observer to make decisions as to whether a move was necessary for an activity to proceed, the observer would have to be subjective and would risk improperly understanding the detailed site requirements. Similarly, the rules avoid the arbitrary classification of activities based on a fixed number of moves once an object had arrived on the jobsite. The rules consider continuation of a move toward the workface as contributory. Time-based averaging reflects the lower efficiency of continued moves.

TEST CASE

A simple case study, of the actual effectiveness of masonry wall construction at a hospital project, tested the applicability of the proposed evaluation method. Within the work area, three workers placed reinforcing steel and concrete masonry unit (CMU) blocks and connected the blocks with mortar.

A videotape of the construction operation enabled an observer to record activities at five and ten second intervals, an appropriate level of detail for application of the VA method in this case. A detailed analysis of approximately 16 minutes generated 800 activities. At each interval the observer recorded the object manipulated, the action performed on that object, and the resource used to perform the action (object, action, resource). The worker performing each activity is an implied resource. For example, the entry reading (mortar, scoop, trowel) indicates that the worker scooped (action) mortar (object) with a trowel (resource).

Once we identified the detailed activities, we manually applied the nine VA rules to a sample time period. Table 2 shows the activity data recorded for a 2:35 minute portion, and the corresponding classifications and weight factors for each task. Worker #3 has a VAEF of 0.30 due to the large number of ineffective activities performed, such as clean, walk and idle. By applying the value-added assessment technique to this operation, the low productivity of worker #3 is apparent. The contractor can now assess whether this worker's VAEF is due to the effectiveness of the construction plan or a result of poor plan implementation. In this case, the ineffectiveness indicates that the worker could have been either eliminated from this operation or given a different role in this activity. For instance this worker could be shared with another team in order to better utilize the worker's time.

The case study indicated that application of the VA method requires significant understanding of the operation in order to properly classify activities. Informed judgment by the observer is necessary to determine the actual purpose of a task. For example, the observer must understand the position of a permanent object indicated by the architectural design in order to determine if the worker placed the object in its final position. In addition, the application of this method in construction plan analysis demands a detailed plan. Finally, it is sometimes necessary to look at successor and predecessor activities in order to correctly classify a particular task. For instance, if a worker picks up a tool to move it out of the way of work, rule #8 will classify the activity (--, pick-up, trowel) as ineffective. However, if a worker picks up a trowel and then butters a block, rule #6 will classify the same activity (--, pick-up, trowel) as contributory.

Time	Worker #1	Rule	Class.	Factor	Worker #2	Rule	Class.	Factor	Worker #3	Rule	Class.	Factor.
0:00:00	mortar, spread, trowel	1	VA	1.0	block, butter, trowel	1	VA	1.0	--, idle, --	9	I	0.0
0:00:05	block, pick-up, --	1	VA	1.0	block, pick-up, --	1	VA	1.0	block piece, align, trowel	4	C	0.5
0:00:10	block, place, --	1	VA	1.0	block, butter, trowel	1	VA	1.0	"	4	C	0.5
0:00:15	"	1	VA	1.0	block, pick-up, --	1	VA	1.0	"	4	C	0.5
0:00:20	block, align, --	3	VA	1.0	block, butter, trowel	1	VA	1.0	"	4	C	0.5
0:00:25	--, pick-up, level	6	C	0.5	--, pick-up, trowel	5	C	0.5	blocks, scrape, trowel	3	VA	1.0
0:00:30	--, pick-up, trowel	6	C	0.5	joints, scrape, trowel	3	VA	1.0	"	3	VA	1.0
0:00:35	joint, scrape, trowel	3	VA	1.0	"	3	VA	1.0	joints, smooth, trowel	3	VA	1.0
0:00:40	--, place/read, level	4	C	0.5	mortar, scoop, trowel	1	VA	1.0	"	3	VA	1.0
0:00:45	"	4	C	0.5	block, butter, trowel	1	VA	1.0	"	3	VA	1.0
0:00:50	--, reposition/read, level	4	C	0.5	block, pick-up, --	1	VA	1.0	--, idle, --	9	I	0.0
0:00:55	block, align, --	3	VA	1.0	block, butter, trowel	1	VA	1.0	"	9	I	0.0
0:01:00	--, set-down, level	6	C	0.5	block, pick-up, --	1	VA	1.0	block, align, level	4	C	0.5
0:01:05	--, set-down, trowel	6	C	0.5	block, place, --	3	VA	1.0	"	4	C	0.5
0:01:10	--, manipulate, line	4	C	0.5	--, pick-up, trowel	5	C	0.5	"	4	C	0.5
0:01:15	"	4	C	0.5	block, tap, trowel	3	VA	1.0	"	4	C	0.5
0:01:20	--, take-out, ruler/pencil	4	C	0.5	joints, scrape, trowel	3	VA	1.0	--, walk, --	9	I	0.0
0:01:25	block, measure/mark, ruler/pencil	4	C	0.5	block, tap, trowel	3	VA	1.0	"	9	I	0.0
0:01:30	--, put away, ruler/pencil	4	C	0.5	joints, scrape, trowel	3	VA	1.0	"	9	I	0.0
0:01:35	--, pick-up, trowel	6	C	0.5	mortar, mix, trowel	4	C	0.5	trowel, clean, --	8	I	0.0
0:01:40	mortar, spread, trowel	1	VA	1.0	block, pick-up, --	1	VA	1.0	"	8	I	0.0
0:01:45	--, idle, --	9	I	0.0	block, butter, trowel	1	VA	1.0	"	8	I	0.0
0:01:50	--, walk, --	9	I	0.0	--, idle, --	9	I	0.0	--, put away, trowel	4	C	0.5
0:01:55	block piece, pick-up, --	5	C	0.5	block, butter, trowel	1	VA	1.0	--, walk, --	9	I	0.0
0:02:00	block, transport, --	5	C	0.5	"	1	VA	1.0	"	9	I	0.0
0:02:05	--, pick-up, hammer	5	C	0.5	block, pick-up, --	1	VA	1.0	--, idle, --	9	I	0.0
0:02:10	block piece, strike, hammer	4	C	0.5	block, place, --	1	VA	1.0	"	9	I	0.0
0:02:15	--, set-down, hammer	6	C	0.5	--, pick-up, trowel	5	C	0.5	"	9	I	0.0
0:02:20	mortar, scoop, trowel	1	VA	1.0	joints, scrape, trowel	4	C	0.5	"	9	I	0.0
0:02:25	mortar, mix, trowel	4	C	0.5	block, tap, trowel	3	VA	1.0	"	9	I	0.0
0:02:30	mortar, scoop, trowel	1	VA	1.0	joints, scrape, trowel	3	VA	1.0	"	9	I	0.0
0:02:35	--, walk, --	9	I	0.0	joints, smooth, trowel	3	VA	1.0	"	9	I	0.0
VAEF			0.61				0.89					0.30

Figure 7: Case Study Data. In a case study involving brickwork, this sample of activities was identified in a video of actual construction. We did the VA classification using the VA classification rules shown in Figure 4.

IX.   CONCLUSION

In order to evaluate the effectiveness of construction plans consistently, across various projects and by different engineers, we created a uniform method to evaluate the effectiveness of detailed construction activities and aggregate plans. The evaluation considers the value of detailed activities from the perspective of an owner. This method is precise to ensure consistent results when applied by different

engineers, and it is also flexible to allow its application in diverse construction operations. The benefits of the method are that it provides overall summary of plan effectiveness, most useful for comparing different plans. In addition to helping select the best plan alternative, the method helps managers by identifying specific activities that contribute value and those that do not directly add value for the owner. Finally, showing specific value-adding and non-value adding activity, it helps engineers find ways to improve methods both on individual jobs and over time.

Nine simple rules classify construction activities into three classification groups. Therefore, construction personnel should be able to employ this method widely. The VAEF method does not require training regarding the classification definitions, but merely a simple understanding of the nine rule groupings and the construction operation being evaluated.

With this method, a planner must decompose high level construction activities into low-level activities that are purely value-adding, contributory, or ineffective. Doing so requires much more detail than is found in a traditional construction master plan. However, these details are required for actual construction, so the knowledge is widely available in practice in the construction industry, and generating the detail in advance helps manage the execution of those details. In addition, the value-added assessment method needs a crew-balancing technique to plan each worker's minute-by-minute activities.

The value-added assessment technique enables different engineers to classify the same activities consistently. Consistent assessment allows comparison of plans and operations that are evaluated by different engineers. Informally, we have found in a Construction Methods class that graduate CE students learned the rules quickly, applied them consistently in a wide variety of construction tasks, and gained deep insight into the effectiveness of construction operations.

Application of the method encourages recognition of the presence of non value-adding activity and understanding the reasons that it is found within a particular construction method. Ultimately, repeatedly asking the question "why" can lead to identification of alternative construction methods that optimize value provided to owners and, over a period of time, reengineering construction processes to use methods that enhance value-added. Highly detailed planning, which the typical CPM construction schedule does not contain, facilitates application of this method. The detailed activity plan includes a time-based list of each worker's activities, defined by the object, action, and resource involved. Considering VA effectiveness will raise consciousness of non-value-adding activities among workers, construction managers, planners, and owners.

Contributory activities will probably never be eliminated completely because construction involves manufacturing a single product at a single location, using varying workforce and resources. The VA analysis method allows distinguishing VA, contributory and ineffective activities. Thus, individual practitioners can emphasize any of these categories of activities as guided by their business conditions.

The VA analysis technique evaluates both the effectiveness and efficiency of a construction method. Most techniques, such as stopwatch studies, only evaluate the output efficiency of a construction method, which does not allow the reengineering of the method prior to its execution. The VA method helps differentiate productivity problems between the effectiveness of a construction method and the actual effectiveness of its execution.

The value-added assessment method requires only simple PC technology for activity classification or VA effectiveness computation. Thus, there are no technical barriers to adoption of the VA assessment method.

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