EQUIPPING THE PROJECT

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The pre-bid study and careful planning of construction methods together with the selection of the most efficient equipment conforming to the planned method is an essential ingredient for successful participation in the heavy construction industry. The use of new, higher horsepower, larger capacity equipment will produce significant savings in the cost or projects. Computer studies using vehicle simulation programs have greatly simplified the selection of equipment that will produce the best costs. Another essential ingredient in a successful and profitable operation is the establishment of a well-planned cost and budget system that provides current production and cost information. The problems presented by high equipment inventories, the obsolescence of older models, and their effect on bonding capacity are restrictive to otherwise technically highly qualified contractors. A more liberal use of mobilization advances would encourage the utilization of newer, more productive equipment. Consequently, the contractor, and ultimately the taxpayer, would benefit from the resulting lower bids on public-works projects.

•EQUIPPING the project is a subject that has been almost "beat to death" over the years by contractors, equipment manufacturers, and engineers. The subject will always survive, however, because the contractor who wants to stay in business must use the newest and latest proven equipment available if he is to participate effectively in what has become one of the most highly competitive industries of our economy.

As one generation of equipment is retired, a new, more productive, and generally more sophisticated breed takes its place. Each successive generation has its own special uses, its own capabilities and, quite frequently, its individual limitations. One very common trait is that, although a piece of equipment may be newer, more productive, bigger, faster, and generally more efficient than its predecessor, it is usually more expensive—more expensive to buy and more expensive to operate. So the contractor faces an ever-growing challenge to get the most from his equipment in order to attain all of the manufacturer's promises. And, to maintain a consistently high production rate, he must find ways to reduce downtime.

In this report I attempt to review the processes that usually influence equipment selection for a project and what effect this has on the persons for whose benefit the work is being done and who ultimately foot the bill—us, the taxpayers.

SELECTING EQUIPMENT FOR THE PROJECT ESTIMATE

It has often been said that a good estimate is half the battle and that the other half of the battle is making it work. In our experience of making estimates for the larger civil projects, we find we must go one step further. We believe that a thorough study and preliminary cost comparison of various construction methods must precede the development of a project estimate. A good estimate and a poor work method will not get the job done. What is required is a good estimate using the best possible method.

The study of methods must not be limited to single transportation schemes. Many times, a combination of haulage vehicles with material-handling systems such as conveyors—or even railroads—will produce the lowest unit costs, but this requires a

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careful study of borrow sources, haul routes, construction sequence, production requirements, and equipment capabilities.

To illustrate the cost-saving opportunities of new or higher productivity units versus older models, I would like to point out the benefits that can be obtained by using newer, higher horsepower, larger capacity units. I will purposely avoid comparing the relative merits of methods, such as bottom dump haulage versus scrapers, but rather will compare the same type of equipment as a class, older models versus newer models. The details supporting my observations are given in Tables 1 and 2.

The haul road on which the vehicles were studied is an actual project involving six different dump locations along the same route, ranging from 7,400 ft to 29,100 ft or about 1.4 to 5.5 miles.

If the 70-ton bottom dump is compared with the 110-ton bottom dump, the larger unit, with a 57 percent greater load capacity, hauls for 17 percent less cost on the short haul and 19 percent less on the long haul. Fleet cost for the larger unit is also less, by 7 and 9 percent for the short and long hauls respectively.

Similarly, comparing the 35-ton rear dump with the 50-ton rear dump shows that the larger unit with a 43 percent greater load capacity hauls for 10 percent less cost on the short haul and 12 percent less on the long haul. Fleet cost is reduced from 27 to 28 percent for the short and long hauls respectively by using the larger truck.

Now, let us compare the 24-cu yd scraper with the 40-cu yd unit. With a 67 percent greater capacity, the larger unit will haul for 16 percent less cost on the short haul and 18 percent less on the longer haul. Here again, fleet cost favors the larger unit, which reduced cost 6 and 9 percent for short and long hauls respectively.

There can be no question that a significant reduction in estimated project costs can result from the application of newer, larger, and more productive equipment. This reduction appears not only in unit costs but also in overall capital cost.

EQUIPMENT AVAILABILITY

The use of more productive equipment reduces the number of vehicles required to obtain a given rate of production. The examples cited show an average of 30 percent fewer bottom dumps and 27 percent fewer rear dumps or scrapers required if large units are chosen. Obviously, fewer units in operation make the operation more sensitive to the mechanical availability of the equipment.

Manufacturers are responding to the need for higher mechanical availability. Many vehicles of recent design include features such as unitized components that are easily removed and replaced, on-board lubrication systems, rapid refueling devices, and more wear-resistant liner material, all of which reduce downtime. The selection of machinery used in the project estimate must consider the availability record of new machinery.

Table 1. Haul road profiles.

	Haul No. 1		Haul No. 2		Haul No. 3		Haul No. 4		Haul No. 5		Haul No. 6	
Road Section	Feet	Percent	Feet	Percent	Feet	Percent	Feet	Percent	Feet	Percent	Feet	Percent
1	2,500	+2.6	2,500	+2.6	2,500	+2.6	2,500	+2.6	2,500	+2.6	2,500	+2.6
2	3,700	+1.7	3,700	+1.7	3,700	+1.7	3,700	+1.7	3,700	+1.7	3,700	+1.7
3	0	+2.0	2,300	+2.0	6,100	+2.0	9,500	+2.0	15,300	+2.0	19,700	+2.0
4	900	+4.0	1,900	+4.0	1,700	+4.0	2,900	+4.0	2,200	+4.0	2,900	+4.0
5	300	+5.0	300	+5.0	300	+5.0	300	+5.0	300	+5.0	300	+5.0
Haul distance	7,400		10,700		14,300		18,900		24,000		29,100	
5	300	+5.0	300	+5.0	300	+5.0	300	+5.0	300	+5.0	300	+5.0
4	900	+4.0	1,900	+4.0	1,700	+4.0	2,900	+4.0	2,200	+4.0	2,900	+4.0
3	0	+2.0	2,300	+2.0	6,100	+2.0	9,500	+2.0	15,300	+2.0	19,700	+2.0
2	3,700	+2.3	3,700	+2.3	3,700	+2.3	3,700	+2.3	3,700	+2.3	3,700	+2.3
1	1,900	+3.4	1,900	+3.4	1,900	+3.4	1,900	+3.4	1,900	+3.4	1,900	+3.4
Return distance	6,800		10,100		13,700		18,300		23,400		28,500	
Cycle distance	14,200		20,800		28,000		37,200		47,400		57,600	

Note: Percent shown is total of grade and rolling resistance.

Table 2. Vehicle comparisons (performance data from published specifications).

Item	Euclid Bottom Dumps B30	Euclid Bottom Dumps B70	Euclid Bottom Dumps B110	Euclid Rear Dumps R35	Euclid Rear Dumps R50	Euclid Scrapers SS24	Euclid Scrapers SS40
Travel time (minutes)							
Haul No. 1	5.82	7.24	6.91	5.64	5.69	6.01	6.91
Haul No. 2	8.14	10.30	9.84	7.85	8.00	8.36	10.04
Haul No. 3	10.50	12.92	12.45	10.11	10.39	10.63	12.68
Haul No. 4	13.80	17.09	16.50	13.23	13.66	13.99	16.90
Haul No. 5	17.02	20.58	19.97	16.36	16.97	17.02	20.40
Haul No. 6	20.56	24.85	24.15	19.73	20.51	20.56	24.70
Haul unit capacity (cubic yards)	21	47	67.5	23.3	33.3	24	40
Number of units required to deliver 3,000 cu yd per 50-min hour							
Haul No. 1	17	10	7	15	11	15	11
Haul No. 2	24	14	9	21	15	21	15
Haul No. 3	30	17	11	26	19	27	19
Haul No. 4	40	22	15	34	25	35	26
Haul No. 5	49	27	18	43	31	43	31
Haul No. 6	59	32	22	51	37	52	37
Haul unit hourly cost (dollars)	22.97	30.75	36.27	25.23	30.71	32.91	37.68
Cost per cubic yard to deliver 3,000 cu yd per 50-min hour (dollars)							
Haul No. 1	0.130	0.103	0.085	0.126	0.113	0.165	0.138
Haul No. 2	0.184	0.144	0.109	0.177	0.154	0.230	0.188
Haul No. 3	0.230	0.174	0.133	0.219	0.194	0.296	0.239
Haul No. 4	0.306	0.226	0.181	0.286	0.256	0.384	0.327
Haul No. 5	0.375	0.277	0.218	0.362	0.317	0.472	0.389
Haul No. 6	0.452	0.328	0.266	0.429	0.378	0.570	0.465
Approximate purchase price (thousand dollars)	47.3	85.6	113.9	86.3	85.5	80.3	102.8
Approximate fleet cost without allowance for spares (thousand dollars)							
Haul No. 1	804	856	797	1,295	941	1,205	1,131
Haul No. 2	1,135	1,198	1,025	1,812	1,283	1,686	1,542
Haul No. 3	1,419	1,455	1,253	2,244	1,625	2,168	1,953
Haul No. 4	1,892	1,883	1,709	2,934	2,138	2,811	2,673
Haul No. 5	2,318	2,311	2,050	3,711	2,651	3,453	3,187
Haul No. 6	2,791	2,739	2,506	4,401	3,164	4,176	3,804

USE OF COMPUTER STUDIES

The use of vehicle simulation by computer makes the selection of methods, vehicle characteristics, and optimum fleet size a matter of routine input of job data, once realistic and truly representative facts have been determined.

Computer studies must carefully tie down all of the variables as a part of input if the results are to have any validity. This is most easily done with an in-house computer. The work, of course, can be farmed out to computer centers. Some major manufacturers of earthmoving construction machinery make their computer services available to prospective purchasers for equipment studies. The customer's own estimator is then usually invited to supply all the special job or application requirements he feels should be considered in applying the equipment to the job.

There is doubt in some quarters regarding the value of computer studies. The magic of electronics has, in a few instances, fallen prey to the "numbers game" that some equipment people play to promote their products. The end result of this type of computer use is often what could be expected only under optimum conditions of grades, road maintenance, performance, availability, tire life, and other factors.

Guarantees for vehicle performance have even been given to prospective buyers based on computerized vehicle applications studies. In a few instances, these computer-generated performance or availability expectations did not materialize, and the guarantees based on them have been disputed. These are isolated cases, however, and should not be construed as an indictment against the use of computers for estimating or other purposes. We must remember that information obtained from a computer is only as good as the information programmed into it.

Properly used, computers are invaluable for studying methods through simulation programs, projecting information, analyzing complex scheduling problems, and accumulating and recording data from a great many sources into the various bid items of a project estimate. Our company uses its computer extensively for these and other purposes.

COMPLETION OF THE PROJECT ESTIMATE

Once construction methods have been determined and the equipment has been selected, a good project estimate must go all the way, in a detailed plan and schedule, from the date of notice to proceed with the work to the final release of contractual liability. The estimate must account for every man- and equipment-hour required to build the job, together with the cost of supplies, permanent material, subcontracts, and overhead necessary to support, equip, and de-equip the project. Add profit, interest on investment, contingencies for escalation in the cost of labor, supplies, and equipment, then add the cost of the bond, and you have the bid estimate. All this may sound simple, but for a complex project it is a long, arduous, and expensive job that usually must be completed in a very short period of time. Some contractors think it is just too much trouble and too costly. Consequently, they rely on a unit cost approach for estimating and a "seat-of-the-pants" approach for planning. This may be one reason, among others, why profits are marginal or nonexistent for some contractors in highway and heavy construction work.

ESTABLISHING A WORK PROGRAM

The game plan of a project estimate is essential. It means a melding of the equipment, the method, and the performance of the work according to some ordered discipline. Many firms use CPM or PERT as added tools, while still others use various unnamed systems that may work best for them.

Most contracts require some sort of schedule to accompany the bid, and many specify periodic updating to assure timely completion of the work. Today's well-managed construction firms recognize that more emphasis must be placed on the study of equipment and methods, the careful preparation of a job estimate, and the development of a detailed construction schedule that is updated as the work progresses. They have learned that any compromise or substitution in equipment, methods, or scheduling without a careful study of the results with the owner can be disastrous. This is the stuff of which unresolved claims and extensive post-job litigation cases are made.

TRYING NEW EQUIPMENT

In view of my foregoing statements, it is appropriate to discuss instances in which a new machine or operating concept pops up elsewhere within the industry during the course of a job. The urge to try something new is almost irresistible. However, the prudent contractor, if he is to try a new machine or new method, must make provision for proving it with the least disruption to his established plan.

Complete reliance on a new piece of equipment can be dangerous even if there is a definite understanding between the manufacturer or dealer and the contractor concerning guaranteed availability and performance before the equipment is put to use. When problems do occur, productive time is invariably lost before corrective measures can be taken. These corrective measures themselves, such as adding more units, cause congestion on roads and in work areas. Congestion disrupts the work sequence, leading to a reduction in productive time and, as a consequence, an increase in the cost of the work being performed. This latter phenomenon can occur even while scheduled production is being maintained. Loading, spreading, processing, or handling machinery geared to a particular mode of delivery may be very sensitive to disruptions. Our company's studies indicate, for instance, that a fill spread whose routine operation is disrupted 25 percent of the time would show a 10 percent increase in its cost; the same spread disrupted 35 percent of the time would show a 17 to 20 percent increase in its cost.

Obviously, no newly designed equipment should be considered as a primary producer until it has been thoroughly proved under actual work conditions. This same principle, to a lesser degree, applies also to new components employed in standard production units. Battles can still be lost for want of the proverbial horseshoe nail in the form of the "we don't stock that part yet" response to field problems.

KEEPING COST RECORDS

The importance of keeping detailed cost records, prepared on a current basis, cannot be emphasized enough. It is only by this means that management knows where the project stands from week to week or month to month, where the trouble spots are, and where corrective measures should be taken to keep the job on schedule and maintain anticipated earnings.

In dealing primarily with contractors involved in larger civil works, our company has frequently noted that even some big firms do not have an accounting system geared to develop detailed equipment costs. A good equipment cost system is invaluable in determining when one should trade in or sell a piece of equipment. Otherwise, a project may be burdened with equipment that has passed the point of diminishing returns.

Accurate and detailed project cost records are essential in making meaningful cost-revenue projections during the course of the work. They also are invaluable for future use as a check on the reasonableness of costs generated in future project estimates.

EQUIPMENT OBSOLESCENCE

"Engineering News-Record" in its April 6, 1972, issue reported that contractors engaged in heavy and highway construction in 1971 had an average current replacement cost investment in equipment ranging from $221,000 to $384,000 per $1,000,000 of contracts. Their average annual equipment purchase was pegged at $27,000 to $43,000 per $1,000,000 in contracts. Thus, the average contractor in this category is apparently carrying on his books, at replacement cost, 5 to 14 years' accumulation of equipment purchases. Although some of this machinery is undoubtedly in the form of high-investment items such as large shovels or similar units, much of it must be machinery that is outdated and long ago superseded by technologically improved items. It has been said that some contractors become emotionally involved with their equipment and are therefore reluctant to dispose of a once-profitable spread, perhaps thinking that the same equipment will perform just as profitably on the next job.

A review of estimates recently made by us that involved 13 domestic earth-filled dam projects having a total value of approximately a half billion dollars and ranging between 3 and 110 million dollars each showed that contractors involved solely with this type of work would require an investment in machinery of approximately $190,000 per $1,000,000 of contract value. The higher equipment investment ratio reported by "Engineering News-Record" suggests a tendency by the larger highway and heavy construction firms to carry higher equipment inventories than is necessary.

Thus it appears that, in general, although the book value of his inventory may be low, the average highway and heavy contractor is encumbered with aging equipment that shows the need for major overhauls. This simply means that unless the machinery is disposed of, it will either be majored, recapitalized, and passed on to the next job at its newer value or be passed on in its present condition, to be repaired at the expense of the upcoming project. In the latter case, it will carry with it not only that cost, but also the burden of its obsolescence.

EQUIPMENT AND BONDING CAPACITY

A contractor's bonding capacity is the after-effect of his overall financial position. It is the result of his ability to complete work using the most productive equipment at the least cost to create earnings equal to, or exceeding, his project estimate projections. Only then can he create a favorable financial condition that maintains or increases his bonding capacity. If the contractor, on completion of a project, carries equipment into his inventory with contingent conditional sales contracts or lease or rental commitments, his bonding capacity may be adversely affected. This is particularly true if the equipment involved is not suitable for work being bid. Thus, a completely experienced and capable contractor may have difficulty in getting a bond.

THE PUBLIC INTEREST

I have discussed some of the problems that face contractors bidding on public-works projects, dealing primarily with these problems as they relate to equipment. Now, let us assume a situation where

1. The best planned method was selected by the contractor;
2. The bid estimate was realistic and supportable;
3. The contractor was awarded the job;
4. Adequate equipment, selected to conform to the method planned by the contractor, was acquired;
5. The game plan was meticulously followed;
6. The job was well managed and good cost and equipment records were maintained; and
7. The job made a reasonable profit.

If all the foregoing took place, the obvious answer is that the contractor bid the job for the best possible price. To that extent, the public interest was served: The taxpayer got the job done for the least apparent cost. The question is, could the taxpayer have benefited more?

It seems to me that, in looking at contracting for public projects, what we as taxpayers are really buying is the expertise to manage the construction of our projects at the least possible cost. However, much of project management's time is now spent on matters involving financing a project—finding means to stretch available capital to cover equipment purchases and other cost matters—rather than on the job itself.

Financing a project, which is primarily an investment in equipment, is one of the major problems facing the contracting business. Some of the burden of financing should be borne by the owner of the project. Mobilization advances, to the extent of major production equipment requirements, would have the effect of lowering the net cost of projects. The procedures involved in such advances have been used successfully for many years by some government agencies. I see no good reason why the same principle cannot be used more frequently, right down to the level of some of the larger municipal projects.

The funds to finance public works usually have been appropriated by the time jobs are awarded. Therefore, there is little added cost to the public for mobilization advances. The bid would not include the cost of commercial interest. The low bidder would have the opportunity to acquire the most productive equipment. Thus, the contractor, properly bonded, would then be giving an implied assurance to the public that it is getting the best performance for the least cost. And that, after all, is what we as taxpayers are striving for.