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MODIFICATION IMPACT EVALUATION GUIDE

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CHAPTER 4

EVALUATION

4-1. General.

a. The revised time schedule developed in Chapter 3 assumes that the contractor will proceed with the unchanged work using the same number of work days per week, the same number of shifts, and the same manpower density as planned before the modification. This approach will minimize, but not eliminate, impact costs; however, its application is limited to those situations where the resulting completion date slippage is acceptable. Nevertheless, even when the Using Agency has indicated that a given completion date is mandatory, it is beneficial to first estimate the modification costs based on this approach, followed by an estimate of the modification costs required to meet the Using Agency's mandatory date. A comparison of the two amounts will enable the Using Agency to reevaluate their position before becoming committed to a course of action that might be economically unjustifiable.

b. When the schedule developed in Chapter 3 is incompatible with an immovable interim or final completion date, the estimator must compress the schedule into the time available by reducing, as required, the duration of activities. This requires that the rate of progress be increased on some -- perhaps most -- activities. In other words, acceleration becomes an element of impact. When acceleration enters the picture, the principle of diminishing returns adversely alters the normal labor cost/productivity ratio. Situations may occur where the impact costs amount to more than the cost of accomplishing the directly changed work. It is likely that the credibility of an estimate producing such results will be questioned by those unfamiliar with the facts; it is therefore important for the estimator's work to be thoroughly documented so its rationale can be defended. The following are applicable to developing the estimate for impact of any cost item:

(1) Has, or will the contractor actually incur an increase in costs?

(2) Is the modification the sole cause of the increase?

(3) Have all feasible actions been taken to reduce or eliminate this cost?

(4) Has it been established that this item does not duplicate any other compensable item included in the estimate for this modification?

c. An affirmative answer is required on <u>all four</u> questions before the item can be included in the cost estimate. The above questions are equally applicable to that portion of the estimate dealing with the direct costs; however, this pamphlet is only concerned with the impact.

4-2. <u>Materials</u>.

a. The effect of impact on construction materials can take several forms. The more common of these are:

(1) Partially completed construction.

(a) Cost of additional temporary protection.

(b) Cost of rehandling.

(2) Materials stored offsite (cost of additional storage time).

(3) Materials shipments (situations may arise where it is desirable to have vendors defer material shipments beyond the originally scheduled date. In these cases, storage costs may be charged by the vendor, and/or freight rates may increase the contractor's cost of obtaining the material. These additional costs are impact-related).

b. The above situations are not all-inclusive since it is impractical to attempt a listing of every possible way that any modification could increase the material-related aspects of a contractor's unchanged work.

4-3. <u>Equipment</u>.

a. Impact costs arising from equipment are similar to those arising from materials in that both are relatively easy to quantify once their applicability is determined. Equipment in this context encompasses all the tools, large and small, assembled by the contractor in support of a construction effort. Typical of modification impacts on equipment are:

(1) Temporarily taken out of service; standby costs.

(2) Rescheduling work causing workspace limitations; reduced productivity.

(3) Disruption of continuity; increased travelling; loss of production time.

(4) Increased iterations of mobilization and demobilization.

b. Only affected equipment is considered in determining the Government's liabilities for impact costs related to equipment. For example, if the contractor has 10 scrapers on the site, but five are down for repairs or deadlined awaiting removal, only the operational five are subject to impact -- and therefore are the only ones included in the cost estimate.

c. The costs of standby time can be developed in a relatively straightforward manner from the applicable equipment rate schedules cited in the contract. (If the contract does not include an equipment rate schedule, costs will be based upon the Contractors' Equipment Ownership Expense Schedule, Sixth Edition, published by the Associated General Contractors of America, Inc. [1966]. Standby costs will not exceed 50 percent of the equipment ownership expense.)(DAR 15-402.1).

d. Reduction in productivity because of equipment crowding or increased travelling time requires a study of the individual situation. The objective of such a study is to define the production time lost to travelling (hours) and the loss of productivity caused by crowding (converted to hours), plus equivalent additional costs for operators and oilers (when applicable).

e. In cases where one or more pieces of major equipment will be removed from service for a long period due to the modification, it is advisable to compare the cost of standby time for the entire period vs. the cost of demobilization and remobilization; whichever amount is smallest should be used in the estimate.

f. Mobilization is defined as the gathering of materials and equipment necessary to accomplish some phase of the construction operation. Demobilization is defined as the equipment removal and cleanup operation following completion of some phase of the work. Since mobilization and demobilization cycles occur frequently on a project, the time and costs required to mobilize and demobilize should be included in the estimate for a modification only when that modification caused the additional cycle. If the additional mobilization/demobilization cycle is related to an unchanged activity, the costs are attributed to impact.

4-4. Manpower.

a. The two major impacts upon manpower are reduced productivity and pay scale increases. The latter is a factor when modifications delay progress to the point that work which would have otherwise been completed must now be performed at a time when higher wages are in effect. Reduced productivity takes many forms, and is therefore more difficult to quantify before the fact.

b. Reduced labor productivity implies a loss from some established normal or anticipated level of productivity. Although construction does not lend itself to definitive measurement of labor productivity, there are methods a contractor can use to quantify anticipated labor costs when preparing a bid. The most common technique draws heavily on data derived from the contractor's past experiences, including any indicated trends, present labor pay rates, and anticipated labor rate increases during the life of the project.

c. The contractor's NAS progress schedule carries lump sum values for each construction activity. However, the ratio of labor costs vs. material and equipment costs varies widely for different activities, so it is impractical to apply a universal rule-of-thumb ratio. Nevertheless, a fairly accurate breakout of labor costs for any activity can be obtained by subtracting from the total activity value all the cost items which are not direct labor. These items are material costs, equipment costs, and overhead and profit. The remaining costs are production labor costs, including wages paid, fringe benefits, insurance and taxes, and overhead and profit markups. Through a process of elimination, a reasonably accurate determination of the manhours represented by the dollar amount of labor cost for an activity can be reached. The Government estimate for the project and data from the contractor's payroll submittals can also be helpful in projecting manpower levels on future activities.

d. That portion of the contract price devoted to labor costs indicates the contractor's anticipated level of labor productivity. Whether or not the anticipated profit can be realized from the completed project depends to a great extent on the contractor's ability to maintain the planned labor productivity level. With expert management and some good luck, the contractor may achieve labor productivity exceeding original expectations. Conversely, labor productivity or effectiveness can fall below expectations as a result of many uncontrollable factors.

e. The actual labor productivity of a project affects the cost of labor for modifications. On projects where actual labor productivity is running at or better than the contractor's anticipated level, data developed from the analysis described in c above is appropriate for prepricing direct and impact costs of modifications. However, when the contractor's actual labor costs are higher (productivity lower) than those anticipated by the bid, actual experience data should be considered. Depending on the degree to which contractor mismanagement has contributed to the higher labor costs, the estimator may find it expedient to use a combination of actual and anticipated productivity projections in arriving at a reasonable labor cost figure for the modification. This does not imply that a modification should be priced to reimburse the contractor for excess labor costs incurred because of his inept management; however, it is possible to incur labor costs higher than those anticipated. The higher costs can occur through no fault of the contractor. The estimator must therefore take this into account when forward-pricing direct or impact-related modification labor costs.

f. This pamphlet deals specifically with the estimation of the costs arising from impact on the unchanged work. It also encourages the settlement of contract modifications before the work is accomplished.

g. Prepricing of impact costs arising from labor is the most difficult aspect of the estimating process for two reasons. First, the estimator must verify that these determinations are reasonable and well founded. Second, when negotiating it is necessary to convince the contractor that the determinations are reasonable. Most contractors (and many personnel within the Corps of Engineers) would prefer to leave the settlement of impact cost/time until after the modification work is performed. However, for the reasons stated earlier, such a procedure is not recommended. The preferred approach is to anticipate the costs before the fact, and to include them in the cost estimate. Figures 4-1a through 4-4 illustrate the effects of various situations on construction manpower efficiency. These figures are included as a source of general information and some estimators may find them helpful in supplementing other data generated in the development of modification cost estimates. However, the validity of the graphs has not been sufficiently tested to warrant their use in preference to established methodologies.

h. The lowest reasonable price for modifications is estimated by basing the direct and impact costs of labor upon the productivity level established in e above. (Allowances for labor impact costs compensate the contractor for losses in productivity.) Typical causes of labor productivity loss on the unchanged work resulting from modifications are as follows.

(1) Disruption. The contractor's progress schedule represents the planned sequence of activities leading to final completion of the project. Workers who know what they are doing, what they will be doing next, and how their activities relate to the successful completion of the project develop a "job rhythm." Labor productivity is at its optimum when there is good job rhythm. When job rhythm is interrupted (i.e., when a contract modification necessitates a revision of the progress schedule), it affects workers on both the directly changed and/or unchanged work and may result in a loss of productivity.

(a) Disruption occurs when workers are prematurely moved from one assigned task to another. Regardless of the competency of the workers involved, some loss in productivity is inevitable during a period of orientation to a new assignment. This loss is repeated if workers are later returned to their original job assignment. Learning curves which graph the relationship between production rate and repeated performance of the same task have been developed for various industrial tasks. The basic principle of all learning curve studies is that efficiency increases as an individual or team repeats an operation over and over; assembly lines are excellent demonstrations of this principle. However, although construction work involves the repetition of similar or related tasks, these tasks are seldom identical. Skilled construction workers are trained to perform a wide variety of tasks related to their specific trade. Therefore, in construction it is more appropriate to consider the time required to become oriented to the task rather than acquiring the skill necessary to perform it. One of the attributes of the construction worker is the ability to perform the duties of his trade in a variety of environments. How long it will take the worker to adjust to a new task and environment depends on how closely related the task is to his experience or how typical it is to work usually performed by his craft. Figure 4-1a assumes that the worker will always be assigned to perform work within the scope of his trade, and that the average worker will require a maximum of one shift (8 hours) to reach full productivity. Full productivity (100 on the Theoretical Productivity Scale) represents optimum productivity for a given project. Figure 4-1b is a tabulation of productivity losses derived from figure 4-1a.

(b) The time required for a worker (or crew) to reach full productivity in a new assignment is not constant. It will vary with skill, experience, and the difference between the old and new task. In using the chart or its tabulation, the estimator must decide what point on the Theoretical Productivity Scale represents a composite of these factors. For example, an ironworker is moved from placing reinforcing bars to the structural steel erection crew. The ironworker is qualified by past training to work on structural steel, but the vast majority of his experience has been with rebars, and the two tasks are significantly different. In view of this, a starting point of "0" is appropriate. The estimator can determine from the chart that a "0" starting point indicates the ironworker will need 8 hours to reach full productivity, with a resulting productivity loss of 4 hours. The Government's liability is then 4 hours times the hourly rate times markups. As a second example, assume the same ironworker is moved from placing reinforcing bars for Building A to placing reinforcing bars for Building B. The buildings are similar but not identical. A starting point of "90" is appropriate. The duration of only 0.8 hours is required to reach full productivity, and the productivity loss is 0.4 hours. The Government's liability would then be 0.4 hours times the hourly rate times markups.

(c) The contractor normally absorbs many orientation/learning cycles as his labor forces are moved from task to task in the performance of the work. Only those additional manpower moves, caused solely by a contract modification, represent labor disruption costs for which the contractor is entitled extra payment.

(2) Crowding. If a contractor's progress schedule is altered so that more activities must be accomplished concurrently, impact costs caused by crowding can result. Crowding occurs when more workers are placed in a given area than can function effectively. Crowding causes lowered productivity; it can be considered a form of acceleration because it requires the contractor either to accomplish a fixed amount of work within a shorter time frame, or to accomplish more work within a fixed time frame. Granting additional time for completion of the project can eliminate crowding. When the final completion date cannot be slipped, increased stacking of activities must be analyzed and quantified.

(a) Activity stacking does not necessarily result in crowding -- when concurrent activities are performed in areas where working room is sufficient, crowding is not a factor. But, if the modification forces the contractor to schedule more activities concurrently in a limited working space, crowding does result. Both increased activity stacking and limited (congested) working space must be present for crowding to become an item of impact cost.

(b) Crowding can be quantified by using techniques similar to those used for acceleration. Figure 4-2 illustrates the curve developed to represent increases in labor costs from crowding. Before applying this curve, the estimator must determine whether crowding will occur and to what degree. For example, the assumption that the contractor's scheduling of the activities in question is the most efficient sequencing of the work must be verified. Perhaps more workers can work effectively in the applicable work space than the contractor has scheduled; if they cannot, perhaps the crowding is not severe enough to justify using the full percentage of loss indicated by the graph. (The graph should be interpreted as representing the upper limit of productivity loss.) In this case, the estimator's judgment of the specific circumstances may indicate that some lower increase factor is appropriate.

(c) For example, assume that the estimator decides that severe crowding will occur in the following situation: The contractor's schedule indicates three activities concurrently in progress in a limited area of the project. Each of these activities employs five workers, placing a total of 15 workers in the area. One of these activities has a duration of 10 days; the other two have 20-day durations. The modification has required that a fourth activity be scheduled concurrently in the same limited area. This additional activity requires three workers; it has a normal duration of 5 days. There are now 18 workers in an area which can only efficiently accommodate 15. The percent of crowding is 3/15 or 20 percent. On the graph (figure 4-2), 20 percent crowding intersects the curve opposite 8 percent loss of efficiency. To find the duration of crowding, the estimator multiplies the normal duration of the added activity by 100 percent plus the percent loss of efficiency. For this example, 5 days times 1.08 equals 5.4 days. Therefore, because of the inefficiency introduced by crowding, the added activity will require 5.4 days to complete. Likewise, on the three affected activities, the first 5 days of normal activity will now require 5.4 days. All four activities will experience loss of productivity resulting from an inefficiency factor equivalent to 0.4 of a single day's labor cost. This is calculated as follows:

Average hourly rate x hours worked per day x number of workers x 0.4 = $ loss

or

$12.00 x 8 x 18 x 0.4 = $691 plus normal labor markups.

3/18 x $691 = direct crowding cost; and should be included in the Direct Cost section of the modification estimate

15/18 x $691 = crowding on unchanged activities, and should be placed in the Impact on Unchanged Work section of the modification estimate.

(3) Acceleration. Acceleration occurs when a modification requires the contractor to accomplish a greater amount of work during the same time period even though he may be entitled to an extension of time to accomplish the changed work. This is sometimes referred to as "buying back time." Acceleration should be distinguished from expediting. Expediting occurs whenever the modification would require the contractor to complete the work before the original completion date included in the contract. Per DAR 18-111, expediting is not permissible in the absence of approval by the Assistant Secretary of Defense (Manpower, Reserve Affairs and Logistics). Acceleration may be accomplished in any of the following ways:

(a) Increasing the size of crews. The optimum crew size (for any construction operation) is the minimum number of workers required to perform the task within the allocated time frame. Optimum crew size for a project or activity represents a balance between an acceptable rate of progress and the maximum return from the labor dollars invested. Increasing crew size above optimum can usually produce a higher rate of progress, but at a higher unit cost. As more workers are added to the optimum crew, each new worker will increase crew productivity less than the previously added worker. Carried to the extreme, adding more workers will contribute nothing to overall crew productivity. Figures 4-3a through 4-3d indicate the effect of crew overloading.

(b) Increasing shift length and/or days worked per week. The standard work week is 8 hours per day, 5 days per week (Monday through Friday). Working more hours per day or more days per week introduces premium pay rates and efficiency losses. Workers tend to pace themselves for longer shifts and more days per week. An individual or a crew working 10 hours a day, 5 days a week, will not produce 25 percent more than they would working 8 hours a day, 5 days a week. Longer shifts will produce some gain in production, but it will be at a higher unit cost than normal hour work. When modifications make it necessary for the contractor to resort to overtime work, some of the labor costs produce no return because of inefficiency. Costs incurred due to loss of efficiency created by overtime work are an impact element because the increase in overtime results from the introduction of the modification. Contractors occasionally find that to attract sufficient manpower and skilled craftsmen to the job, it is necessary to offer overtime work as an incentive. When this is done, the cost must be borne by the contractor; however, if overtime is necessary to accomplish modification work, the Government must recognize its liability for introducing efficiency losses. Figure 4-4 is the result of study which attempted to graphically demonstrate efficiency losses over a 4-week period for several combinations of work schedules. These data are included merely as information on trends rather than firm rules which might apply to any project. Although figure 4-4 data do not extend beyond the fourth week, it is assumed that the curves would flatten to a constant efficiency level as each work schedule is continued for longer periods of time.

(c) Multiple shifts. The inefficiencies in labor productivity caused by overtime work can be avoided by working two or three 8-hour shifts per day. However, additional shifts introduce other costs. These costs would include additional administrative personnel, supervision, quality control, lighting, etc. Modifications that cause the contractor to implement shift work should price the impact cost as appropriate for the activity being accelerated. Environmental conditions such as lighting and cold weather may also influence labor efficiency.

(4) Morale. The responsibility for motivating the work force and providing a psychological environment conducive to optimum productivity rests with the contractor. Morale does exert an influence on productivity, but so many factors interact on morale that their individual effects defy quantification. A project's contract modifications, particularly a large number, have an adverse effect on the morale of the workers. The degree to which this may affect productivity, and consequently the cost of performing the work, would normally be very minor when compared to the other causes of productivity loss. A contractor would probably find that it would cost more to maintain the records necessary to document productivity losses from lowered morale than justified by the amount he might recover. Modification estimates do not consider morale as a factor because whether morale becomes a factor is determined by how effective the contractor is in his labor relations responsibilities.

4-5. Quantification. The following example demonstrates how to use figures 4-3a through 4-3d to quantify the impact costs of crew overloading. Assume that the contractor has planned a construction operation with a duration of 15 working days and an optimum crew size of 10. The modification now requires that the contractor accomplish this operation in 10 working days. The rate of production is the unit of work per amount of effort in mandays. The percent increase is new rate minus original rate divided by original rate times 100. Thus,

$$\frac{(1 \text{ job} \div 100 \text{ MD}) - (1 \text{ job} \div 150 \text{ MD})}{1 \text{ job} \div 150 \text{ MD}} \times 100 =$$

$$\frac{.01 - .0067}{.0067} \times 100 = 50 \text{ percent}$$

This represents a 50 percent increase in the crew's rate of production. From figure 4-3 a or 4-3 d, it appears likely that 50 percent production gain can be achieved by increasing the size 80 percent. Other options could be implemented to speed up production: the optimum crew could work longer shifts, more days per week; a second crew could be placed in operation (if allowed by the nature of the work). However, for this example only increasing crew size is considered. The way to quantify the impact cost before the fact is:

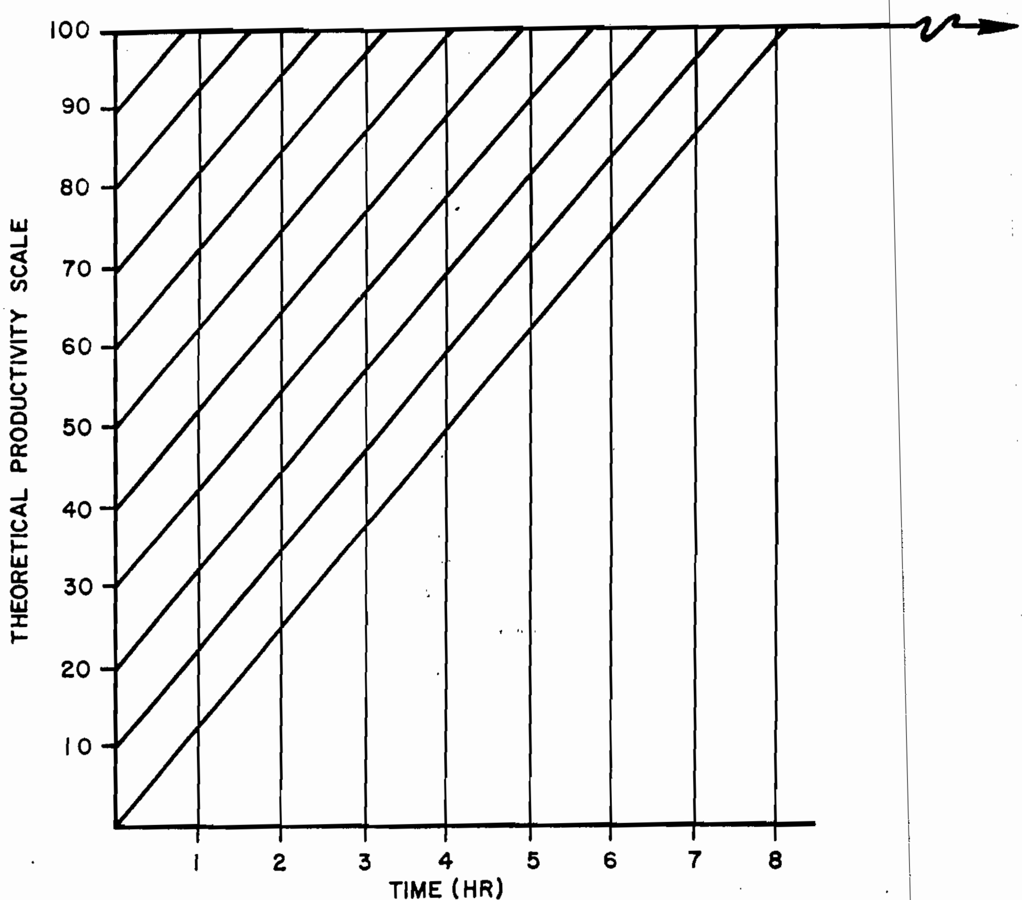
	Original Plan	Accelerated Plan
Manpower	10	18
Hourly Rate	$12	$12
Crew Cost/Day (8 hours)	$960	$1,728
Duration (Working Days)	15	10
Crew Cost (Cost/Day x Duration)	$14,400	$17,280
Taxes, Insurance, Fringes (18 percent)	$2,595	$3,110
Total Crew Cost	$16,992	$20,390

Impact Cost (Accelerated-Original) = $3,398 ($3,400)

- or -

Impact Cost (Accelerated Plan x Efficiency Loss) =
$20,390 x 16.7 percent (from fig. 4-3 b), = $3,405 ($3,400)

The amount of $3,400 would be placed in the modification estimate, under "Impact on Unchanged Work" and identified by the activity involved. Increased cost of supervision, if necessary, is not included in this crew overloading analysis. Supervision must be costed separately, either as a separate item or as an element of Job Site Overhead, as appropriate.



*100 REPRESENTS THE PRODUCTIVITY RATE REQUIRED TO MAINTAIN SCHEDULED PROGRESS

Figure 4-1a. Construction operations orientation/learning chart.

(BASED ON CONSTRUCTION OPERATIONS
ORIENTATION / LEARNING CHART)

PRODUCTIVITY STARTING POINT	DURATION (HR)	AVERAGE LOSS (HR)
100	0	0
90	0.8	0.4
80	1.6	0.8
70	2.4	1.2
60	3.2	1.6
50	4.0	2.0
40	4.8	2.4
30	5.6	2.8
20	6.4	3.2
10	7.2	3.6
0	8.0	4.0

Figure 4-1b. Productivity losses derived from figure 4-1.1.

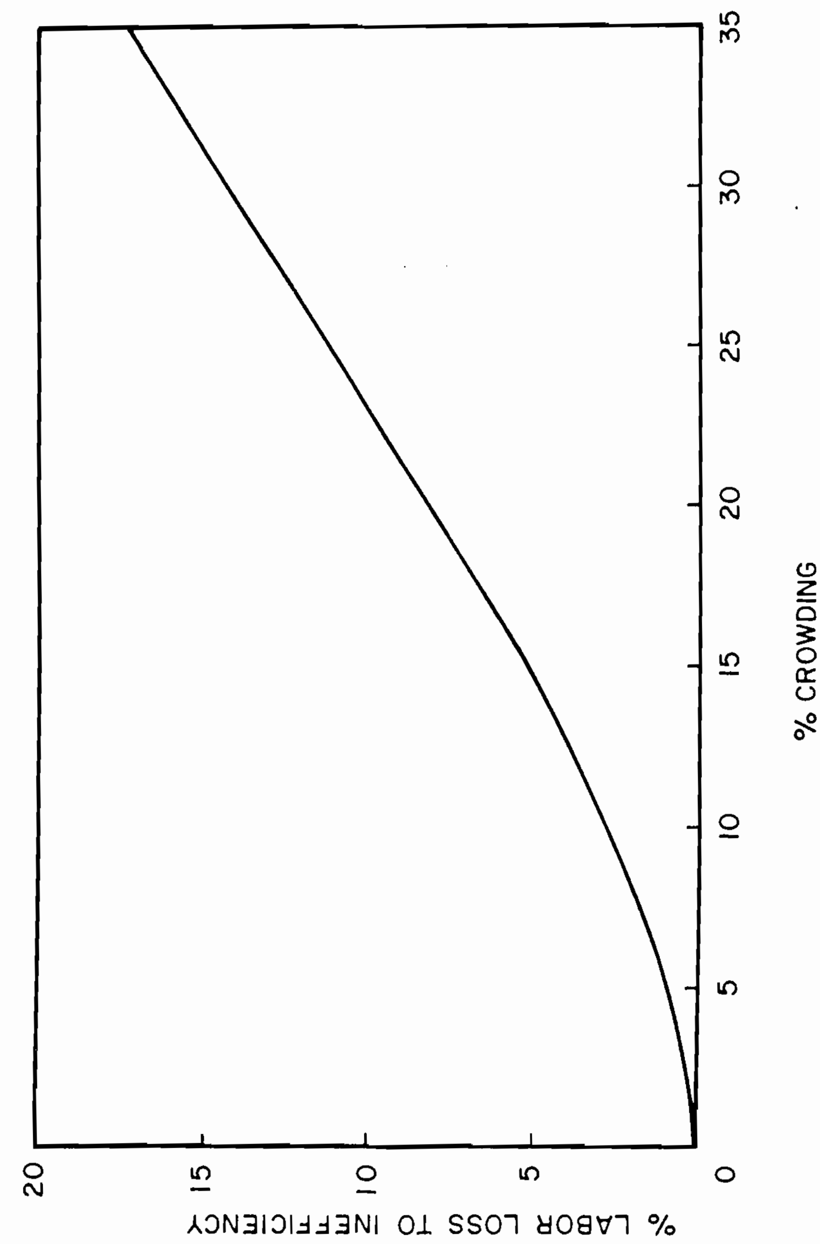


Figure 4-2. Effect of crowding on labor efficiency.

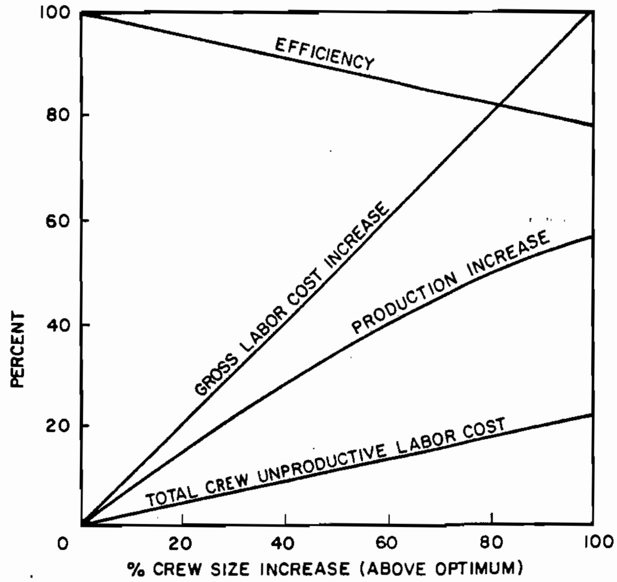


Figure 4-3 a. Composite effects of crew overloading

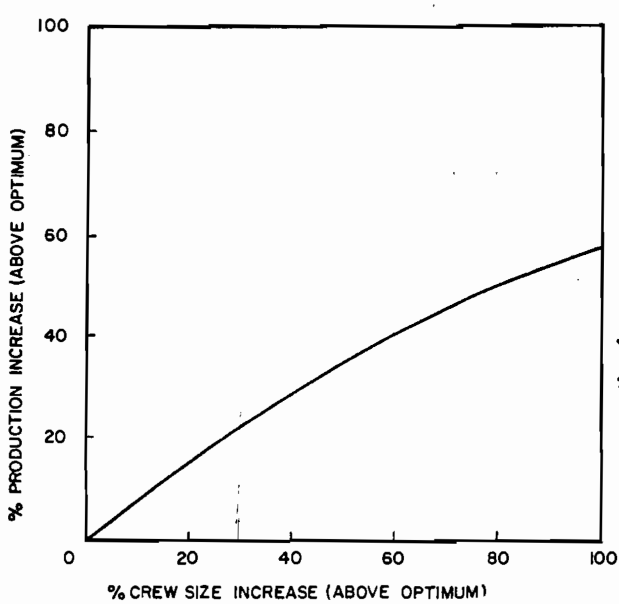


Figure 4-3 b. Unproductive labor at crew overloading.

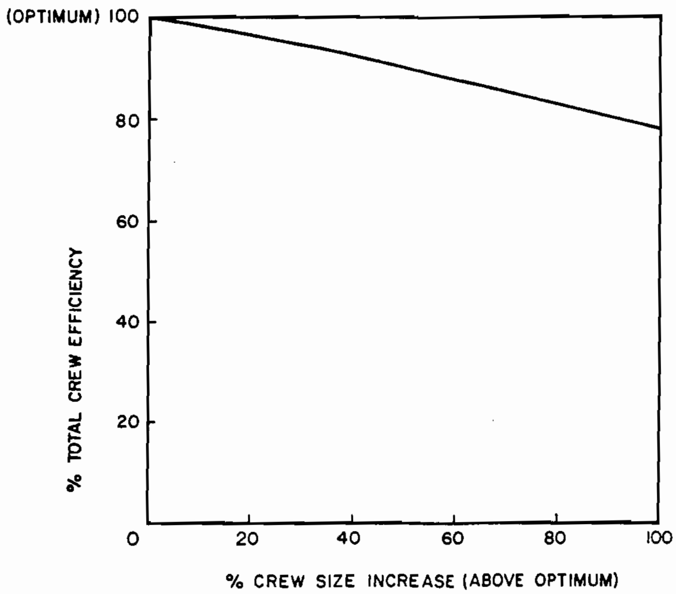


Figure 4-3 c. Efficiency of crew overloading.

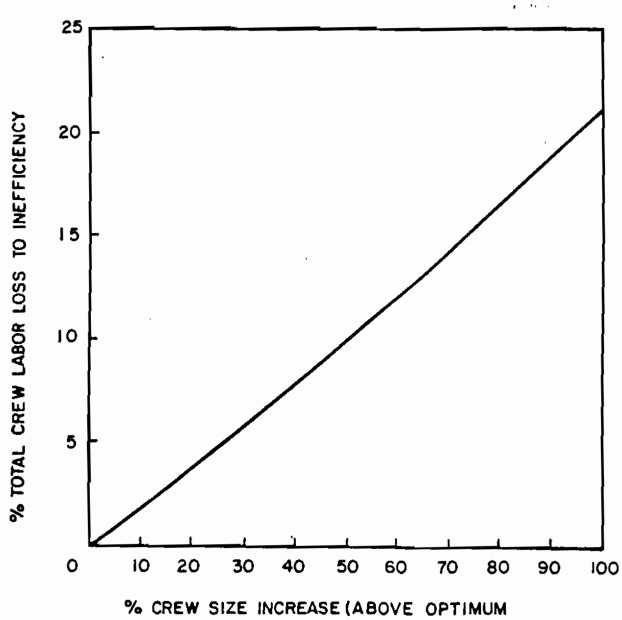


Figure 4-3 d. Production gain of crew overloading.

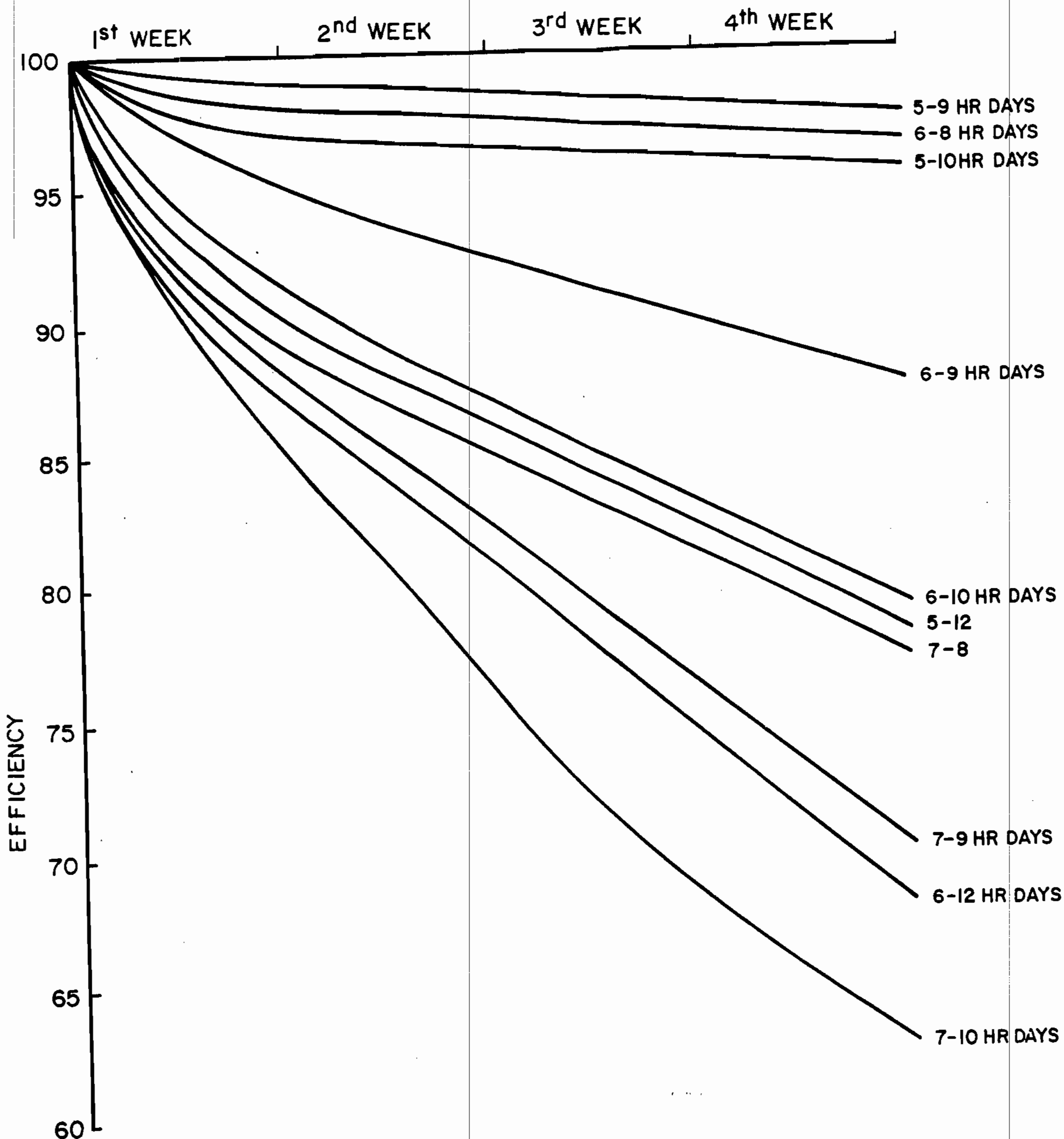


Figure 4-4. Effect of work schedule on efficiency.