EST.08

Construction Productivity

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Controversy surrounding construction productivity is rooted in the differences in data collection. It is incorrect to assume that productivity is measured uniformly and that all published productivity values have the same basis. This paper examines data collection requirements, force reports, crew mix, and value-improving practices that prevent critical estimating miscalculations. It includes productivity tables comparing basic construction crafts in major oil refining capital projects and a discussion of the pros and cons of using incentive-driven or rule-bound contractors for a project. The paper compares the value of analyzing productivity for each craft to an aggregate of the construction productivity value, and it discusses how to use productivity and other related adjustments that are necessary for estimating purposes.

PRODUCTIVITY

Productivity is the average direct labor hours to install a unit of material. In a perfect world, perfect productivity (1.0) would be accomplished in a 40-hour work week, with everyone taking all of their holidays and vacation days as planned. All of the engineering drawings would be 100 percent complete, there would be no delays of any kind, everyone would work safely, everything would fit perfectly the first time, the weather would be 70 degrees fahrenheit, and there would be no litigation at the end of the project.

THE PROBLEM

Unfortunately, we do not live in a perfect world, and true productivity is often poorly understood. The first challenge in understanding productivity is the lack of common terms. One such failing is in defining craft crew mix. The definition of hours identified as "direct labor" must be consistent. This fact is quickly ignored, and this leads to misunderstanding that one contractor is less productive because they have twice as many hours. Truthfully, the contractor with twice as many hours might be more productive because half of the hours are indirect hours and not direct labor hours.

Second, much of the focus in determining productivity is incorrectly placed on the individual worker. Productivity has little to do with the worker because many workers work at the same rates. It is often the jurisdictional rules and technology surrounding the workers, not the workers themselves, that hinder productivity. Improper or incomplete planning, like out-of-sequence work, also contribute to lower productivity because of the rework hours required to complete the original task.

Finally, it is incorrect to assume that data used in productivity studies have the same data basis. Productivity is not based on wage rates or cost data. For this reason, it is improper to combine wage rate, hours, and material quantities to make productivity comparisons.

TYPICAL MISCONCEPTION

For example: The project's construction is 70 percent complete and the productivity remains 1.0 which is based upon our estimate which already had a built in lower productivity. This statement exemplifies the problem with productivity.

First, they confused accounting terminology with productivity terminology. What this statement suggests is an improper accounting system rather than good productivity. Second, they suggest that the worker's output has remained constant. It is nearly impossible for productivity to remain constant for any activity where people have been working long hours in less than ideal environments. The only time productivity has any chance to remain constant is with a highly automated robotic assembly line.

Finally, without proper labor hour data, there is no way to back up the statement. While most projects collect material quantities reasonably well, they do not perform as well in collecting hours. Most projects believe that lump sum contracts mean they are absolved from collecting data because the contractor will be held accountable for the total cost. The reason for collecting data is to forecast and assist the contractor to successfully complete the project as a team. It is better to assist and get data than it is to fail and end in litigation.

Of course, discussing productivity is like discussing contingency: everyone has an answer but no reference point or data. As a result, a common mistake made by project teams is that published productivity numbers all have the same basis. This assumes that all industries use the same estimating systems, collect data in the same manner, have the same detail granularity of data, use the

Table 1—Direct Labor Basis

Mechanical	No.
Boilermaker GF	1
Millwright FM	1
Boilermaker FM	0
Equipment Op FM	0
Ironworker FM	1
Millwright	2
MW Hlprs - 7th Period	4
Boilermakers	2
Boilermaker Hlprs - 2nd yr.	6
Laborer	1
Laborer - 1st yr	3
Equip Op > 50 Ton	1
Equip Op	2
Ironworkers	1
Ironworker Hlprs -3rd yr.	2

Pipe / Welding	No.
Pipe GF	1
Area FM	1
Pipe FM	3
Welding FM	1
Pipefitters	7
Pipefitter App 7th 6 mos	14
Pipefitter App 2nd 6 mos	21
Combo Welders	7

Structural Iron & Rigging	No.
Struct.Iron GF	1
Ironworker FM	3
Rigging FM	1
Ironworkers	6
Ironworker Hlprs -3rd yr	14
Ironworker Hlprs -1st yr	14
Struct.Welders	3
Riggers	2
Rigger Hlpr	2
Equip Op > 50 Ton	2

Concrete	No.
Carp. GF	1
Carp FM	2
Cement Mason FM	2
Ironworker FM	1
Laborer FM	1
Carpenters	6
Carp.Hlprs - 7th Period	14
Carp. Hlprs - 1st Period	14
Equip Op Grp 4	2
Ironworkers	2
Ironworker Hlprs -3rd yr	4
Cement Mason	4
Labors - 1st yr	8
Survey Inst.Man	1
Rodman	1

Civil	No.
Equipment Op FM	1
Laborer FM	1
Carp FM	1
Equip Op Grp 6 >50t	3
Equip Op Grp 4	6
Carp. Hlprs - 1st Period	4
Labors	1
Labors - 1st yr	4
Survey Inst.Man	1
Rodman	1

E & I	No.
Electrical GF	1
Electrical FM	2
Inst Tech FM	2
Electricians	5
Electrician Apprentice	10
Conduit Fitter	6
Tubing Fitter	6
Inst Techs	5
Inst Techs Apprentice	5

Insulators - Asb. Certified	No.
Insulator GF	1
Insulator Lead FM	0
Insulator Area FM	0
Insulator FM	2
Insulators Mechanic	5
Insulator Apprt - 3rd Year	10
Insulator Apprt - 1st 6 mos	10

Painters	No.
Painter GF	1
Painter FM	2
Painter	10
Painters 3rd yr Period 5	20

same contractors, have the same weather conditions, have the same facilities, etc. There are significant differences in building the same facility at two different locations within the same industry. Rather than invest in data collection and developing an internal gold standard, project teams will scour information systems seeking numbers to prove a specific point. Generally, they borrow and mix several outside references to paint a picture.

GOLD STANDARD

A gold standard is necessary to adequately assess productivity. A gold standard for productivity should address reference location, direct labor basis, and bandwidth. These three areas allow for understanding productivity on a worker basis and the outside influences on the worker.

If the gold standard for concrete is 10 hours/cubic meter, then productivity is based how the actual or estimated hours compares to the gold standard. For example: 12 hours/cubic meter represents a productivity that is 20 percent worse than the gold standard. Productivity, as referenced in this article, for the project is the actual hours divided by the gold standard hours. A productivity value greater than 1.0 is worse than the gold standard, so 12 hours/cubic meter has a productivity value of 1.2.

Ideally, the reference location should have more than half of the total project data population. Project team members should be familiar with the reference location and most should have some work experience in that location. This assists team members with understanding productivity issues between the reference location and the benchmarked location.

Direct labor basis, table 1, describes the crew mix ratios and the crafts that are considered direct labor for calculating productivity. Labor accounts for area or craft superintendents, expeditors, document control, scaffolding, etc. are indirect construction hours. Hours associated with the crew mix in table 1 enable an analysis of productivity on a worker basis. Collecting hours, direct or indirect, not addressed in table 1 assist with analyzing outside influences on overall productivity imposed on the worker. Therefore, firewatch, holewatch, and equipment operator positions are considered indirect labor. If indirect hours are included in productivity calculations, then the productivity calculation could be noticeably higher.

In table 1, the bold blue text identifies the direct labor that works directly on the asset under construction. The bold black text, at the top of each craft section, identifies the overhead supervision that should be charged to direct labor. The black text at the bottom of some craft sections identifies the support labor that should be charged to direct labor. This table represents the average crew mix basis for a 1.0 productivity labor index for a project.

Many other productivity studies have been made using at least 500,000 direct labor hours as a standard study basis. It would be appropriate to aggregate a few smaller projects together to achieve a total project size of 500,000 hours. It would be best if all the projects have similar distribution of hours in all the major construction accounts.

When evaluating productivity, it is important to understand that productivity must be compared on a bandwidth and not on a point basis. Productivity should be expressed as being the average hours per unit of material within a bandwidth. If the data accuracy is +/-15 percent, then productivity has a bandwidth at least as wide as the data accuracy. Therefore, to state that productivity for site A is different than site B, the average productivity value would have to be outside the accuracy range, bandwidth, of site A.

THE DATABASE

The research database currently consists of 54 process types, 516 cost models, and over 2,500 projects. The data includes project definition, process unit types, construction resource loading, cost, and schedule. The database contains projects that were executed at 12 locations across the United States and two locations in Northern Europe. From this database, a subset of a few hundred projects were selected for their detailed information regarding cost, scope, contingency level, and project evolution starting with a class V estimate to the actual completed cost. The predominant population of the data is for projects completed after 1997. Projects used in this study ranged from 300,000 to 1,000,000 direct labor hours to obtain an average near 500,000 direct labor hours.

THE STUDY

The most significant issues that affect productivity, schedule types and crew mix, are highlighted by comparing two major contractor types. When schedule and crew mix are analyzed on the same basis, there is little difference in the base (worker) productivity. Given this, it is scheduling and crew mix issues that add significant hours to a project.

RULE-BOUND CONTRACTORS

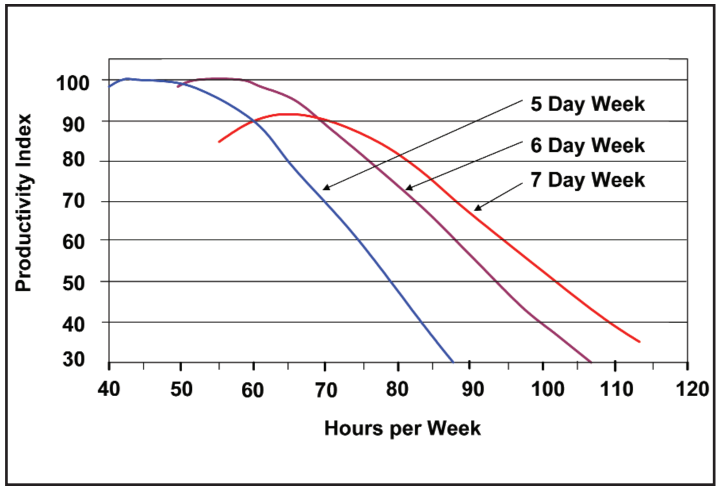

Figure 1—Productivity Index v. Hours Per Week

Rule-Bound contractors manage craft workers utilizing jurisdictional rules. These jurisdictional rules are very important to establishing crew mixes, definition of each craft, work hours, and overtime. Productivity can be significantly hampered by inefficiencies caused by craft jurisdiction, which prevents one craft from performing work in another craft's jurisdiction. For example, the laborer for piping may not be allowed to assist or carry the tools for the electrical craft.

INCENTIVE-DRIVEN CONTRACTORS

Incentive-Driven contractors objective is to discourage inefficiencies and waste. Incentive-Driven construction firms generally have no collective bargaining agreement, can manage their own work force, and can re-deploy workers to any craft needing help. In other words, they can improve productivity by having mixed crews work in a single area.

SCHEDULE

In 1989, a Houston-area facility underwent a significant revamp which lasted five years. All types of schedules were utilized throughout this period, and a productivity study for all the different shifts was made. The study involved rigorous surveys at the jobsite using various means to avoid disturbing the workforce. It took four years to develop objective findings. Figure 1 summarizes productivity based on three major schedules, five-day, six-day and seven-day).

Five-Day Work Week (x) is between 40 and 80 hours:

$$y = -0.03784x^2 + 3.1708x + 34.268$$

equation 1

Six-Day Work Week (x) is between 50 and 100 hours:

$$y = 0.000591x^3 - 0.1536x^2 + 11.5169x - 166.425$$

equation 2

Seven-Day Work Week (x) is between 60 and 114 hours:

$$y = 0.000529 X^3 - 0.1519 x^2 + 13.0155x - 259.1325$$

equation 3

Work schedules with two shifts need the productivity index multiplied by 0.925 because this introduces an additional work start/stoppage for one day. In this case, the loss of productivity is due to congestion cause by two shifts swapping places.

The nomenclature for referencing the schedules will be expressed in the format of days and hours per day. Therefore, 5-10s will mean that the schedule was a five-day week working 10-hour days.

The study found that productivity is better using 4-10s than 5-8s because it reduces the number of breaks, start-up and stoppage of work. Using 4-10s provides eight hours out of 10 for working hours, producing 32 hours per week. This is better than 5-8s, which produce six hours out of eight producing 30 hours per week.

The workers behaved the same during the 5-8s as they did for 4-10s, and the big savings were in one less mobilization and demobilization per week. This also allowed for working the fifth day if overtime is required or if there is a day off due to poor weather conditions.

The study found that using 5-8s is better than 4-10s for safety reasons. It appeared that this was not significant in general except for the winter months when a 4-10 schedule exposes the workers to low light or, in some cases, darkness at the beginning and the end of the shift. The consideration here is that it would be more effective to change the schedule from 4-10s to 5-8s during the three months that have the shortest daylight, i.e. November, December and January. People react negatively to change, and it takes time to recover. There is a possibility that there may be productivity loss and the scheduler will have to perform a breakeven analysis.

The study found that a 5-10 schedule is the best overall schedule for construction, especially in the Gulf Coast area. The productivity difference between a 40-hour week and this schedule was very minor. This shift achieved the best overall schedule for the project. Additionally, since the better craftsmen prefer a 50-hour week instead of a 40-hour week, a better labor force was attracted. Overtime pay is a consideration in this schedule.

The study found that a 6-10 schedule was not as good as hoped. The productivity dropped off significantly so that there is only a marginal benefit from its use. Productivity did not drop off as much if it was only worked for two to three weeks. It is not worth the overtime in most cases.

The study found that a 7-10 or 7-anything schedule is a disaster. The productivity is so bad that the project will take significantly longer if this schedule is used for any length of time. This schedule should only be considered for turnarounds.

The results were just as bad for turnarounds, two shifts in 24 hours, as they were for 7-10s. The first two weeks of a turnaround will net some work progress, but after that, the progress was the same for a six-day schedule. An acceptable alternative on a turnaround is to work 14 days and then start giving everyone a rotating day off each week or every 10 days. This allows keeping the workforce as big as possible. Regardless, the workers will pace themselves and will start taking days off anyway, so it is better to preschedule their days off where it can be controlled.

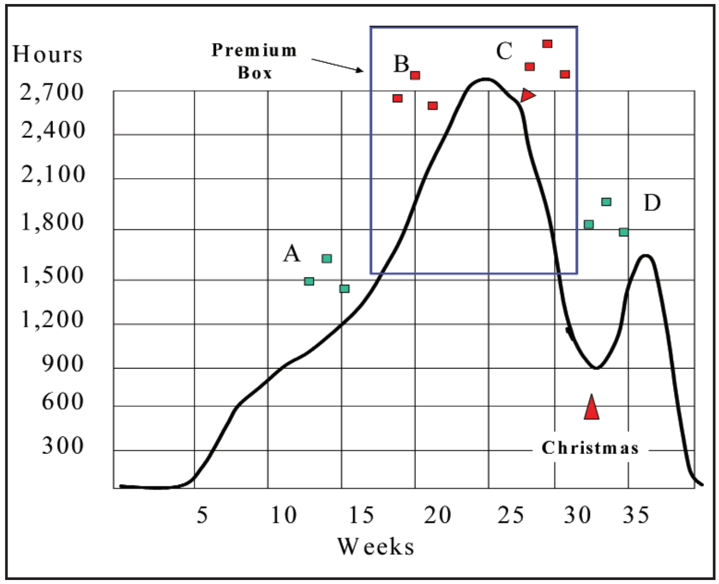

Figure 2—Resource Loaded Curve

OVERTIME

Research data on craft resource loading, from the database, provides a data-driven viewpoint on overtime productivity. Given the way overtime is commonly used, there is virtually no payout and almost nothing but downside to a project. Offering workers 5-10s is sometimes the only way to get the workforce to show up for large projects. Overtime must be minimized on large projects and utilized only to the extent that is necessary to keep the workforce.

If there is a need for overtime to meet schedule, it would appear that overtime should be worked for very specific activities that help the productivity of the normal work hours. A premium box is shown in figure 2. This premium box is the period of time that overtime has negligible return on investment. During this period of time several things occur:

- Labor density is at its maximum value;
- Congestion is at its maximum value;
- Work week is probably over 50 hours.

This is the time when project managers authorize overtime in an attempt to recover schedule. Overtime in this period means working two 60-hour shifts or placing workers on 70-hour weeks. Since the project is six months into construction, the workers have started pacing themselves a few months earlier. More money will be expended in payroll, but little schedule duration will be recovered. There are four data points in figure 2 that show overtime periods: A, B, C and D. Points B and C were the actual overtime periods for the project. It was hoped that the project schedule could recover six weeks of schedule delay. The project depicted in Figure 2 still overran by six weeks, completed in 42 weeks.

Overtime works best when it is used for less than three weeks and has at least three months between overtime intervals. Just like the first two weeks of a turnaround, there will be some net work progress, but after that, the worker will adopt a 50-hour work pace.

Table 2—Rule-Bound Crew Mix

Pipe / Welding	No. A	Base Wage Rate B	Wage Mult A X B	Notes
Pipe Supt	0	31.50	0.00	(1a)
Pipe GF	1	31.50	31.50	(3a)
Area FM	1	30.50	30.50	
Pipe FM	3	30.25	90.75	
Welding FM	1	30.25	30.25	
Expediter	1	29.00	29.00	(1a)
Document Cont.	0		0.00	(1a)
Clerk	0		0.00	(1a)
Pipefitters	7	29.00	203.00	
Pipefitter App 7th 6 mos	14	21.75	304.50	
Pipefitter App 2nd 6 mos	21	14.50	304.50	
Combo Welders	7	29.00	203.00	
Firewatch/Holewatch	10	19.62	196.20	(2a)
Teamsters	2	21.75	43.50	(4a)
Base Wage Rate	**68**	21.57	1466.70	

Notes
(1a) Construction Indirect
(2a) Assigned to Crew
(3a) Construction Indirect
(4a) Other Support (e.g.: bus drivers)

	% of Base	$/Hr
Construction Service Labor	14	3.02
Field Service Labor	16	3.45
Burden and Benefits	**21**	4.53
Fringes	**53**	11.43
Temporary Services	9	1.94
Small Tools	6	1.29
Rental Equipment	30	6.47
Inspection	5	1.08
Consumables	7	1.51
Overhead and Fee	15	3.24
Premium Pay (overtime)	20	4.31
Delay	7	1.51
Scaffolding	15	3.24
Total	218	47.02
All In Wage Rate		**68.59**

Table 3—Rule-Bound Crew Mix with No Apprentices

Pipe / Welding	No. A	Base Wage Rate B	Wage Mult A X B	Notes
Pipe Supt	0	31.50	0.00	(1b)
Pipe GF	1	31.50	31.50	(3b)
Area FM	1	30.50	30.50	
Pipe FM	3	30.25	90.75	
Welding FM	1	30.25	30.25	
Expediter	1	29.00	29.00	(1b)
Document Cont.	0		0.00	(1b)
Clerk	0		0.00	(1b)
Pipefitters	7	29.00	203.00	
Pipefitter App 7th 6 mos	14	29.00	406.00	(5b)
Pipefitter App 2nd 6 mos	21	29.00	609.00	(5b)
Combo Welders	7	29.00	203.00	(5b)
Firewatch/Holewatch	10	29.00	290.00	(2b)
Teamsters	2	29.00	58.00	(4b)
Base Wage Rate	**68**	29.13	1981.00	

Notes
(1b) Construction Indirect
(2b) Assigned to Crew
(3b) Construction Indirect
(4b) Other Support (e.g.: bus drivers)
(5b) No Apprentices Available

	% of Base	$/Hr
Construction Service Labor	14	4.08
Field Service Labor	16	4.66
Burden and Benefits	**21**	6.12
Fringes	**53**	15.44
Temporary Services	9	2.62
Small Tools	6	1.75
Rental Equipment	30	8.74
Inspection	5	1.46
Consumables	7	2.04
Overhead and Fee	15	4.37
Premium Pay (overtime)	20	5.83
Delay	7	2.04
Scaffolding	15	4.37
Total	218	63.51
All In Wage Rate		**92.64**

The best way to maximize the return on investment for overtime is to schedule overtime before and after the construction period depicted by the premium box. The best option for a scheduler is to plan periods of overtime in the construction schedule rather than reactively scheduling overtime for a crisis or schedule slip. Very few projects avoid overtime. Having scheduled overtime builds in planned schedule recovery. If this schedule is necessary, the project can realize meaningful work progress.

Scheduling overtime at point A would have resulted in schedule recovery, adding back in schedule float, at a time when time and materials are manageable. If the schedule inside the premium box consumed the float because of material shortage, poor weather, or other unexpected events, then more overtime could be schedule at point D. Point D offers more advantages than point A because additional staffing does not have to be obtained because it occurs on the de-staffing side of the construction period. It is much simpler to retain workers than to hire them in an overtime emergency. This means that the de-staffing plan will have to be reviewed and possibly extended, which is less costly than mobilization.

The worst time to schedule overtime is just ahead of a major holiday like Christmas. In the example shown in figure 2, there is no return on investment for scheduling overtime in point D. The only way for this project to have any chance of schedule recovery would have been to have started the construction phase so that it completed before Christmas. The other alternative would have been to have planned a two-week slowdown and planned for the project to have completed in January.

Too many projects expect that overtime scheduled as depicted by points B and C in figure 2 will recover schedule. Do not use overtime in a reactive manner, and do not schedule it next to a major holiday. Scheduling overtime as depicted by point D would be an excellent choice to recover schedule if this was a time other than a major holiday.

CREW MIX

A typical hierarchy in construction will have an area superintendent over several general foremen. This superintendent's time is included in construction indirects. The general craft foreman is part of the craft crew mix and is included in the direct labor account. A standard crew mix of 1 craft foreman (CF) to eight workers is average, 1 CF to 10 workers is adequate. One CF to six workers, for example, one journeyman, three apprentices and two laborers, is used when schedule is critical and the client is concerned about schedule performance.

When construction crews are predominately populated with journeymen, it will be reflected in the craft's crew mix. Depending on the trade, apprentices are upgraded to journeyman after a period of five years. Apprentice salaries are increased at a constant rate until they achieve the journeyman's rate in their fifth year. When construction sites do not utilize apprentices, the average base wage rate is driven up as much as 10 percent. Using a higher percentage of journeymen does not increase productivity enough to offset the increased cost of the base wage rate.

Incentive-driven contractors allow laborers to be trained to work in firewatch and holewatch activities. These same contractors also employ trained laborers in scaffolding. It is not unreasonable to require that apprentices be trained for these same functions. One site requires carpenter craftsmen to perform scaffolding and journeymen to perform fire-watch and hole-watch labor. Sometimes apprentices are not allowed to work in electrical crafts for safety reasons. All these examples have a huge affect on the labor wage rate but not necessarily on the productivity.

To make a fair assessment of productivity, the crew mix for each craft must be understood. The crew mix for piping is displayed in tables 2, 3 and 4. Productivity analysis is based on the incentive-driven crew mix shown in table 4. Remember to remove indirect labor hours from the labor data. This can be easily performed if the daily force reports are collected. These reports have detailed labor accounts along with data about absentees, weather/site conditions, and work restrictions. Without analysis of the daily force reports, a thorough analysis of productivity cannot be satisfactorily performed. Daily force reports are a requirement and are readily available for any project. Whether the contract is reimbursable or lump sum, daily force reports must be filed with the project.

Table 2, rule-bound crew mix, displays what is normally assumed by project managers for their projects. This was a standard crew mix over ten years ago. However, there is a decline in skilled labor in construction. The rule-bound contractors actively recruit and support apprenticeship programs to build a skilled labor pool, but it is becoming difficult to recruit apprentices.

Table 3, the rule-bound crew mix with no apprentices, shows the affect that the lack of apprentices has on a crew mix wage rate. Most contractors now have mature work forces. Apprentices have completed their five-year apprenticeships and there are no new recruits. Incentive-driven constructors are not immune to the decline in skilled work force. The advantage they have is that they capitalize on their flexibility to assign qualified workers to any position. Incentive-driven contractors have fewer craft jurisdiction restrictions. The table showing incentive-driven crew mix, table 4, shows that they need 54 workers to do the same work as 68 rule-bound workers. They maximize the non-productive time of workers. For example, if the welder apprentice is idle, they will fill the firewatch position required in the area while the welder journeyman is working.

Table 4—Incentive-Driven Crew Mix

Pipe / Welding	No. A	Base Wage Rate B	Wage Mult A X B	Notes
Pipe Supt	0	31.50	0.00	(1c)
Pipe GF	1	31.50	31.50	(3c)
Area FM	1	30.50	30.50	
Pipe FM	3	30.25	90.75	
Welding FM	0	30.25	0.00	(5c)
Expediter	0	29.00	0.00	(1c)
Document Cont.	0		0.00	(1c)
Clerk	0		0.00	(1c)
Pipefitters	7	29.00	203.00	
Pipefitter App 7th 6 mos	14	21.75	304.50	
Pipefitter App 2nd 6 mos	21	14.50	304.50	
Combo Welders	7	29.00	203.00	
Firewatch/Holewatch	0	19.62	0.00	(2c)
Teamsters	0	19.62	0.00	(4c)
Base Wage Rate	**54**	21.63	1167.75	

Notes
(1c) Covered by Field Service Labor
(2c) Covered by Apprentices or Construction Service Labor
(3c) Direct Labor
(4c) Covered by Construction Service Labor (Indirect)
(5c) Covered by Field Service Labor (Indirect)

	% of Base	$/Hr
Construction Service Labor	14	3.03
Field Service Labor	16	3.46
Burden and Benefits	**30**	6.49
Fringes	**0**	0.00
Temporary Services	9	1.95
Small Tools	6	1.30
Rental Equipment	30	6.49
Inspection	5	1.08
Consumables	7	1.51
Overhead and Fee	15	3.24
Premium Pay (overtime)	20	4.33
Delay	7	1.51
Scaffolding	15	3.24
Total	174	37.63
All In Wage Rate		**59.25**

In all three crew mix tables, a standard construction indirect account is shown. The only significant difference is in two accounts: burdens and benefits and fringes. When evaluating bids, there is essentially no difference between the base rate of a rule-bound, table 2, and incentive-driven, table 4, worker. The area that will add significant cost to the project is if there are no apprentices, table 3. If so, the base wage rate increases nine dollars per hour, or about 40 percent. The all-in wage rate increases 35 percent.

RULE-BOUND VS INCENTIVE-DRIVEN

To calculate an overall productivity index, a few projects were selected to acquire hours for each major construction account. The projects were selected based on similar demographics. The

Table 5—Overall Productivity Index Calculation

		PT	Crew Mix: Incentive Driven Standard A	Crew Mix: Rule Driven Standard B	Crew Mix: Rule-Driven Normalized C
	Hours	% of Total			
Mechanical	504,299	0.08	1.47	2.10	1.79
Piping	3,687,132	0.51	1.54	1.92	1.63
Instrumentatior	331,709	0.05	1.00	1.06	0.90
Electrical	715,932	0.11	2.84	2.66	2.26
Concrete	714,705	0.10	1.12	1.07	0.91
Civil	378,681	0.07	2.13	1.52	1.29
Steel	459,013	0.06	1.19	1.63	1.39
Insulation	67,410	0.02	1.28	1.37	1.16
Paint	34,074	0.01	1.10	1.52	1.29
Total	6,892,955	1.01			
Average	765,884				
			Overall Productivity		
Weighted Average			**1.63**	**1.84**	**1.57**
Weighted Delta				**0.21**	**-0.06**

workers have essentially the same standard of living, and the contractors have worked at each of the sites over several decades. Each project has labor hour distributions that are very close to the percent of total account hours shown by column PT in table 5. The average for all the accounts is 765,884 hours, which meets the minimum of 500,000 hours necessary to provide a standard productivity calculation.

Overall Productivity Index = S (PT X A)

equation 4

An overall productivity index is calculated by summing the product of the craft's productivity and the percent of total labor hours. This requires productivity values for each craft to be known. The overall accuracy for this type of calculation is generally +/-15 percent.

Column A in table 5 is an average United States Gulf Coast (USGC) labor index at a incentive-driven site. Column B is the labor index for a mid-west rule-bound contractor. Column C is the same mid-west labor index adjusted to match the crew mix of the USGC site. Unadjusted, the rule-bound contractor shows that it is 21 percent, 0.21, less productive than the incentive-driven contractor. When the crew mix is adjusted, the rule-bound contractor has 6 percent, -0.06, better productivity.

The next challenge for the contractor is maintaining a distribution of first year to fifth year apprentices. The all-in wage rate is dependent on the lower wage earners. Another solution to improve the competitive wage rate is to allow laborers to fill scaffolding, firewatch, and holewatch positions.

PRODUCTIVITY INDICES

Table 6, productivity index by region, is based on projects with similar characteristics for each of the regions shown in figure 3. The table shows the calculated regional productivity indices,

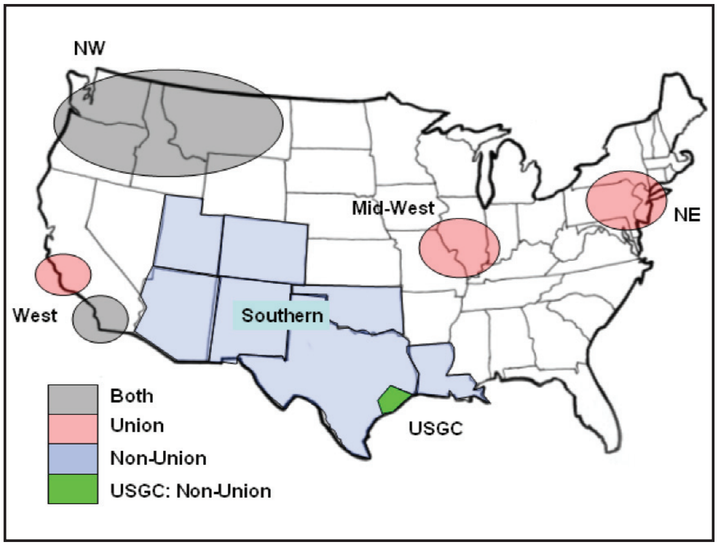

Figure 3—Productivity Regions

>1.0 is lower productivity, <1.0 is lower productivity, across the United States and the predominant contractor type. Regional productivity indices are calculated in the same manner as an overall productivity index, as shown in table 5). All the values are relative to the USGC value. If the USGC value is adjusted for a typical 50-hour work week, its value becomes 1.23 and all other values must be adjusted accordingly.

RETURN ON INVESTMENT

In choosing contractors, the deciding factor is who will give the highest return on investment. A 15 percent return on productivity would have to be proven in faster completion rates or shorter schedules. There would have to be cases where the rate or schedule is noticeably better than the overall accuracy of the data pool. For example, assume that the resource loading curve, figure

Table 6—Productivity Index by Region

Region	Contractor	Regional Productivity Index	Inverse
NW	Incentive	0.86	1.16
Southern	Incentive	0.93	1.08
USGC	Incentive	1.00	1.00
West	Incentive	1.21	0.82
NW	Rule	1.32	0.79
Mid West	Rule	1.34	0.79
West	Rule	1.45	0.69
NE	Rule	1.50	0.67

2, analysis demonstrates that the average completion rate for a craft is about three percent per week of the total budgeted hours. If productivity is 15 percent better, the contractor must demonstrate that they can average nearly four percent per week to have a return on productivity. This means that the work must briefly peak at five percent per week a few times during the construction schedule. Data for projects over 800,000 hours average three percent with no peaks over four percent per week for both rule-bound and incentive-driven contractors.

To determine if a rule-bound contractor delivers 15 percent better productivity, the average schedule duration should be at least 15 percent shorter. The overall accuracy of aggregated schedule durations is +/-10 percent. For any contractor to claim 15 percent better productivity, there must be schedules that excel the overall accuracy level of the collected data. For a 15 percent improvement on productivity, the example project, figure 2, would have to reduce the schedule by 6 weeks (33 to 24 weeks).

No discussion of productivity is complete without first normalizing the basic dataset and establishing commonality of terminology used. Productivity studies need to adopt a gold standard to provide a standard basis for productivity comparisons.

The use of overtime in the schedule should be a strategic tool and used to accrue schedule float to offset unexpected delays. It would be better to set a schedule that is close to the normal work schedule and then pay the worker a premium.

Improving productivity should be focused on eliminating jurisdictional inefficiencies that hinder the individual worker.

Actually, both union and non-union can operate in a rule-bound or incentive-driven mode. So, there is no difference in union and non-union but there is a huge difference in the work rule practices for either depending on the site and the restrictions placed on the contractor.

Project estimates must be supported by current site practices to be creditable and to improve predictability. Estimating should incorporate local practices, which include considerations for crew mix, staffing requirements, jurisdictional rules, and schedules. From a practical perspective, the best estimating practice would be to use the average construction hours based on common local labor practices.

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