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Standard Practice for Job Productivity Measurement[1]

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INTRODUCTION

Job Productivity Measurement (JPM) measures both construction productivity differential on an ongoing and periodic basis and average productivity over the life of the construction project.

JPM calculates the ratio of output per unit of input: how much work—Construction Put In Place (CPIP)—was produced by how many labor hours. Additionally, JPM is an early warning signal for construction performance. It measures ongoing productivity changes, trends, and anomalies resulting from changes on a construction jobsite, which enables contractors, project managers, supervisors, and foremen to react and improve productivity as the construction project unfolds.

1. Scope

1.1 Based on the UNIFORMAT II format for organizing building data, established in Classification E1557, and depending on the level where measurement is applied (industry, total job, or building element), JPM measures construction productivity at three levels: task, project, and industry (shown in Fig. 1). By comparing labor hours used against CPIP, JPM allows for unified measurement of established building elements (according to the UNIFORMAT II format. This practice establishes a process for measuring construction job productivity by comparing labor usage to CPIP.

1.2 JPM measures labor productivity of the installation processes on a construction job.[2]

1.3 CPIP is measured with input from the labor performing the installation, utilizing elements of statistical process control (SPC) and industrial engineering.

1.4 JPM takes into account the difficulty of installation at any given point on a job.

1.5 JPM evaluates relative productivity changes using trend monitoring.

2. Referenced Documents

2.1 *ASTM Standards:*[3]

E631 Terminology of Building Constructions

E833 Terminology of Building Economics

E1557 Classification for Building Elements and Related Sitework—UNIFORMAT II

E1946 Practice for Measuring Cost Risk of Buildings and Building Systems and Other Constructed Projects

E2166 Practice for Organizing and Managing Building Data

E2587 Practice for Use of Control Charts in Statistical Process Control

2.2 *ASTM Manual:*[4]

MNL 65 Application of ASTM E2691 Standard Practice for Job Productivity Measurement

3. Terminology

3.1 *Definitions*—For definition of general terms related to building construction used in this practice, refer to Terminology E631; and for general terms related to building economics, refer to Terminology E833.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *baseline labor hour budget, n*—a budget of direct labor hours created at the onset of a new construction project that approximates how many hours will be spent on any defined part of the project.

[1] This practice is under the jurisdiction of ASTM Committee E06 on Performance of Buildings and is the direct responsibility of Subcommittee E06.81 on Building Economics.

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[2] JPM is based on the application of Job Productivity Assurance and Control (JPAC), which has been used in industry for more than fifteen years, resulting in 20 to 30 % improvement in productivity for contractors using it.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] Available from ASTM International Headquarters. Order MNL65-EB.

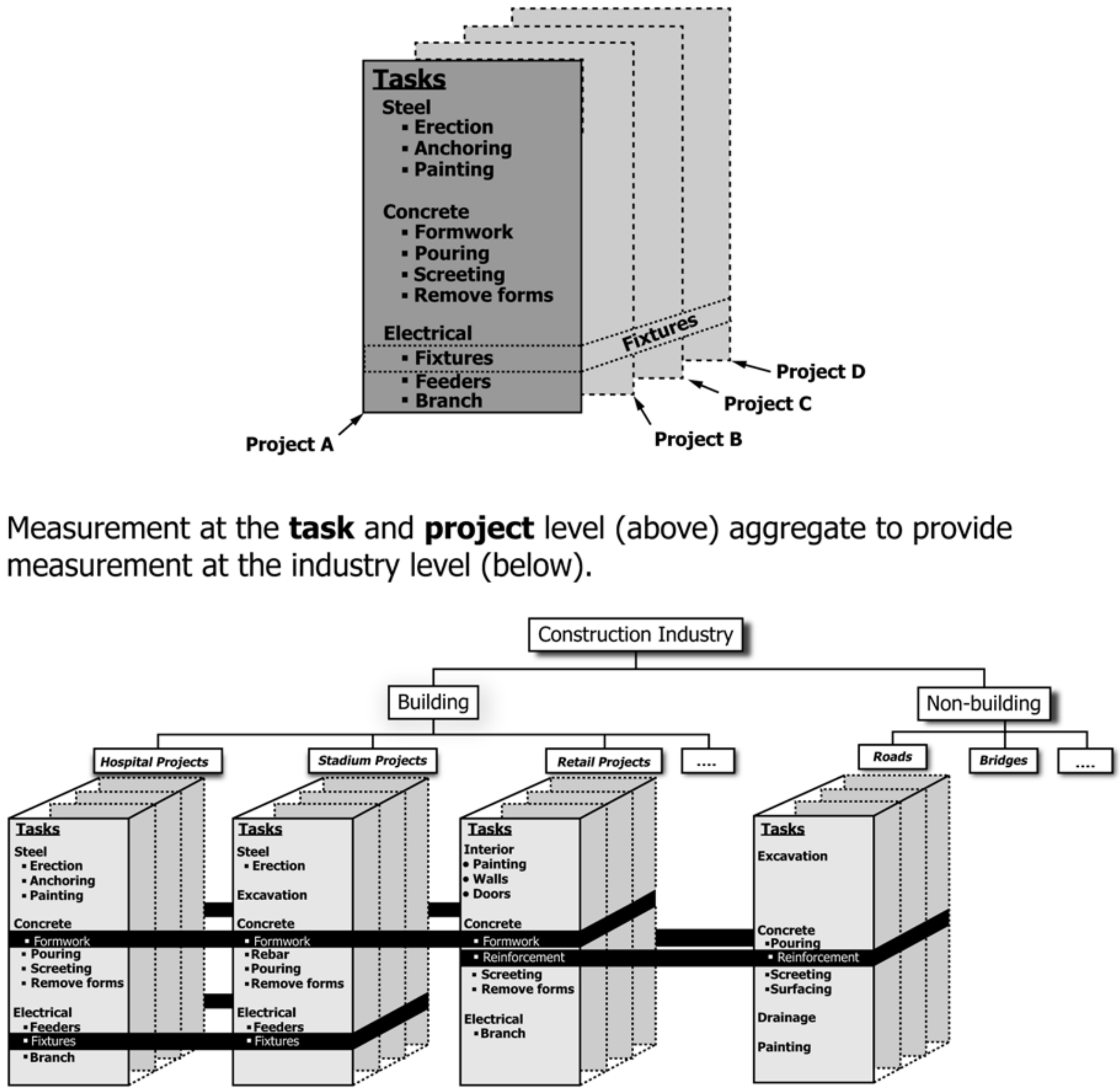


FIG. 1 Measurement of Productivity at the Industry, Project, and Task Level

3.2.1.1 *Discussion*—The budgeted hours are first assigned to the tasks on the project, and can be summed to determine budgeted hours for any cost code or for the entire project.

3.2.2 *control signal, n*—in construction, any series of data points which indicates deviation from the expected job progress in relation to labor, material, or finance, and indicates anomalies on the jobsite to the contractor, project manager, or job supervisor.

3.2.2.1 *Discussion*—In the Job Productivity Measurement Standard Practice, a control signal identifies any deviation from the labor productivity reference point.

3.2.3 *labor productivity reference point, n*—a ratio calculated at the beginning of a construction project, for the hours needed to complete one percent of the construction, based on the baseline labor hour budget.

3.2.4 *non-installation hours, n*—labor hours spent on activities other than installation, removal, or erection of material on the jobsite including, but not limited to, hours spent on prefabrication, preassembly, job-layout, supervision, or job planning.

3.2.5 *observed percent complete, n*—a percentage number estimate, based on physical observation, that documents what portion of a jobsite task, cost code, or entire project has been completed.

3.2.6 *productivity differential, n*—in JPM, a measurement of the percent difference between the labor productivity reference point and the current labor productivity for the given timeframe.

3.2.6.1 *Discussion*—In the Job Productivity Measurement Standard Practice, job productivity is defined as the rate of production over time, and measures the ongoing and periodic changes in productivity over time. If more hours are used than planned due to the difficulty of installation, errors, or rework, the job productivity differential will be negative. If fewer hours are used than planned, the job productivity differential will be positive.

3.2.7 *system productivity, n*—the ratio of the labor hours allocated to physical construction put in place,[5] over the total labor hours used for completion of the project.

4. Summary of Practice

4.1 This practice is organized as follows:

4.1.1 *Section 1, Scope*—Identifies coverage.

4.1.2 *Section 2, Referenced Documents*—Lists ASTM standards referenced in this practice.

4.1.3 *Section 3, Terminology*—Addresses definitions of terms used in this practice.

4.1.4 *Section 4, Summary of Practice*—Outlines the contents of this practice.

4.1.5 *Section 5, Significance and Use*—Explains significance of measuring job productivity and of using the JPM practice to do so.

4.1.6 *Section 6, Procedure*—Lists the steps for conducting JPM.

4.1.7 *Section 7, Data Sources and Assumptions*—Describes raw data used in calculation of JPM.

4.1.8 *Section 8, Calculation of Labor Productivity Reference Point (LPRP)*—Describes calculation of LPRP, using data gathered according to Section 7, and with output provided for Section 9.

4.1.9 *Section 9, Calculation of JPM*—Provides algorithms for determining JPM.

4.1.10 *Section 10, Report*—Describes various types of reporting output for JPM.

4.1.11 *Section 11, Applications*—Describes where and how JPM information can be used.

4.1.12 *Section 12, Keywords*—Lists related words and phrases.

5. Significance and Use

5.1 JPM produces two measurements: construction production rate and productivity.

5.1.1 JPM measures the overall production rate by comparing CPIP to the time elapsed in the construction schedule.

5.1.2 JPM measures overall job productivity through a comparison of labor usage to a reference point.

5.2 JPM issues early warning signals for construction.

5.2.1 JPM identifies productivity deviations in the form of any gains or losses in productivity, and anomalies indicating a special cause, from the productivity reference point.

5.2.2 JPM measures the productivity changes to individual building elements (according to the UNIFORMAT II format for organizing building data, in Classification E1557) with the same methodology used for overall job productivity measurement.

5.2.3 JPM measures ongoing changes in labor usage.

5.3 JPM measures productivity wherever the labor is used in construction by:

5.3.1 Any contractor or construction manager directly or indirectly responsible for the productivity of the labor and its usage.

5.3.2 Any contractor or construction manager conducting self performance on any portion of the construction job.

5.3.3 Any contractor or construction manager supervising labor performance on any portion of a construction job.

6. Procedure

6.1 Establish a baseline labor hour budget (BLHB) for the scope of the construction job being measured using a Work Breakdown Structure (WBS) and reference to the UNIFORMAT II classification (Practice E1557).

6.2 Evaluate the BLHB for appropriate level of detail.

6.3 Establish the labor productivity reference point (LPRP).

6.4 Once any labor hours are expended on the job (even before installation commences, with activities such as planning, layout, pre-assembly), begin tracking the JPM.

6.5 Report the JPM productivity differential and review the results for signals of special causes[6] impacting the productivity.

7. Data Sources and Assumptions

7.1 There are four data sources required for the calculation of JPM:

7.1.1 An estimate of the scope of construction to be put in place (see 7.2).

7.1.2 The BLHB developed from a work breakdown structure (WBS) (see 7.3).

7.1.3 Expended labor hours (see 7.4).

7.1.4 CPIP, measured by observed percent complete (see 7.5).

7.2 The estimate of the labor required for installation is established prior to establishing the BLHB.

7.2.1 Profit on the project is calculated based on estimated labor cost with given labor hours; therefore, the BLHB must not exceed the estimated labor hours.

7.3 A WBS comprised of cost codes and tasks is needed to establish the BLHB as described in Section 8.

7.3.1 The UNIFORMAT II classification (Practice E1557) provides a format for creating a WBS by defining a hierarchy of building elements; Practice E2166 provides a practice for organizing building data based on UNIFORMAT II.[7]

7.3.1.1 JPM users managing several contractors or subcontractors have subcontractors reporting JPM for each of the major group elements and group elements defined in UNIFORMAT II.

7.3.1.2 Contractors and subcontractors directly managing installation report JPM for major group elements, using cost codes similar to the individual elements from UNIFORMAT II. For example, the cost codes for an electrical contractor include

[5] Construction put in place is defined in the C30 series report from the U.S. Census Bureau on "Value of Construction Put in Place," http://www.census.gov/.

[6] As defined by Practice E2587, a special cause (or unassignable cause) is a factor that contributes to variation in a process or product output that is feasible to detect and identify. In JPM measurement, the factor contributes to variation in productivity or deviation from the productivity reference point.

[7] UNIFORMAT II is limited to building construction, whereas JPM applies to all types of construction, including roads and bridges, tunnels, dams, and railroads.

service and distribution, lighting and branch wiring, communication and security systems, and special electrical systems, as shown in Fig. 2.

7.3.2 Establish cost codes that will remain standard across all jobs within the company. Use a maximum of 20 cost codes. Seven to twelve cost codes are effective for most applications.[8] Reference the descriptions listed as individual elements in Section 3 of UNIFORMAT II for creating cost codes.

7.3.3 Depending on the application level of JPM, tasks are defined by either UNIFORMAT II, or when applied at the project level, are generated and described individually as a subset of each cost code.

7.3.4 A partial example of a WBS based on UNIFORMAT II is shown in Fig. 3, where UNIFORMAT II Level 2 and 3 are shown for an electrical contractor, and detailed tasks have been assigned to Level 3 for the Service and Distribution.

7.3.5 The WBS includes tasks for both installation and non-installation activities.

7.3.5.1 Non-installation activities include, but are not limited to, planning, layout, pre-fabrication and assembly, and supervision.

7.3.5.2 Non-installation hours are included as tasks within the cost codes to which they apply.

7.3.6 The baseline labor hours are assigned to the lowest level tasks of the WBS, establishing $BLHB_{Task}$ for each task.

7.4 On the project level application of JPM, labor hours expended are reported in each cost code. This method of time reporting must be consistent with time reported for payroll purposes. Hours are not reported for any level lower than the cost codes in the WBS. In other words, hours are not collected or reported by individual activities.

7.5 CPIP is the observed completed portion of each task (observed percent complete), contributing to the total completion of that task, based on effort expended.

NOTE 1—Observed percent complete will take into account the difficulty of installation of each task. For example, the first five hundred feet of a one thousand foot pipe installation could be a straight run, giving observed percent complete of fifty percent. The second five hundred feet of the installation could be more difficult, requiring more labor hours. Therefore, the ratio of construction put in place to labor hours spent will not be a linear relationship. In this example, the first five hundred feet could use 250 out of 1000 hours, where the second five hundred feet could use 750 out of 1000 hours.

8. Calculation of Labor Productivity Reference Point

8.1 The WBS created in 7.3 is used to create the BLHB, which is then evaluated and used to establish the initial LPRP.

8.2 Create a BLHB for the job.

8.2.1 Data from 7.3.6 provides budgeted labor hours for each task in the WBS. Use either the budgeted labor hours specific to a job based on company past practice or, if that data is not available, use an industry standard reference point such as R.S. Means Cost Estimating guide (**1**).[9]

8.2.2 Determine the BLHB for each cost code by summing the BLHB for each task within the cost code at the lowest level of the WBS, according to Eq 1:

$$BLHB_{CostCode} = \sum_{Tasks} BLHB_{Task} \quad (1)$$

8.2.3 Determine the BLHB for the total job by summing the hours budgeted in each cost code, as shown in Eq 2.

$$BLHB_{Job} = \sum_{CostCodes} BLHB_{CostCode} \quad (2)$$

8.2.4 The summed cost code hours comprise the total direct labor budget for the job. An illustration of a conversion from the WBS into a BLHB is shown in Table 1.

8.3 Evaluate the BLHB.

8.3.1 Calculate the contribution of each $BLHB_{Task}$ to its associated cost code, and to the overall job (Eq 3 and 4).

$$\text{BLHB Task Weight per Cost Code} = \frac{BLHB_{Task}}{BLHB_{CostCode}} \quad (3)$$

$$\text{BLHB Task Weight per Job} = \frac{BLHB_{Task}}{BLHB_{Job}} \quad (4)$$

8.3.2 Common practice has shown that a task representing more than 2.5 % of the total job will be difficult to visualize for reporting observed percent complete. If any $BLHB_{Task}$ is greater than 2.5 % of $BLHB_{Job}$, divide the task into more detailed tasks.

8.3.3 Continue to divide tasks as necessary and reallocate hours until each $BLHB_{Task}$ is less than 2.5 % of the $BLHB_{Job}$. Examples of BLHB task weightings are shown in Table 2, columns 4 and 5.

8.3.4 Calculate the LPRP for each cost code as the BLHB required for one percent of CPIP (Eq 5).

$$LPRP_{CostCode} = \frac{BLHB_{CostCode}}{100} \quad (5)$$

8.3.5 Calculate the LPRP for the total job by summing the $LPRP_{CostCode}$ of each cost code weighted by the $BLHB_{CostCode}$ as a portion of the $BLHB_{Job}$ (Eq 6).

$$LPRP_{Job} = \sum_{CostCodes} \left(LPRP_{CostCode} \cdot \frac{BLHB_{CostCode}}{BLHB_{Job}} \right) \quad (6)$$

NOTE 2—One percent of a cost code ($LPRP_{CostCode}$) is not equal to one percent of the total job due to the fact that each cost code has a different impact on the job and is therefore weighted against the total job. In other words, one percent completion of each cost code could be higher or lower than one percent completion of the job. The cost code weighting is done to ensure that JPM takes into account the difficulty of installation based on the cost code being measured. Eq 6 takes weighting of the cost code into account and is a summation of weighted $LPRP_{CostCode}$, and therefore will not be equal to the simple summation of all $LPRP_{CostCode}$.

8.4 Account for change orders.

8.4.1 The budgeted labor hours associated with change orders are added or subtracted from the BLHB, and are included in the calculation of the baseline productivity from the point at which they are recognized by the labor performing installation.

8.4.2 Note reasons for change orders as part of the JPM.

9. Calculation of JPM

9.1 Evaluate the JPM periodically by collecting CPIP and expended labor hours, and comparing them to the LPRP.

[8] For reasons similar to those listed in 6.1.3 of Practice E1946, 20 elements provides an appropriate level of detail for measuring job progress without oversimplifying the JPM, or placing undue burden on the field labor for tracking required for the JPM.

[9] The boldface numbers in parentheses refer to a list of references at the end of this standard.

Level 1 Major Group Elements	*Level 2 Group Elements*	*Level 3 Individual Elements*
A SUBSTRUCTURE	A10 Foundations	A1010 Standard Foundations A1020 Special Foundations A1030 Slab on Grade
	A20 Basement Construction	A2010 Basement Excavation A2020 Basement Walls
B SHELL	B10 Superstructure	B1010 Floor Construction B1020 Roof Construction
	B20 Exterior Enclosure	B2010 Exterior Walls B2020 Exterior Windows B2030 Exterior Doors
	B30 Roofing	B3010 Roof Coverings B3020 Roof Openings
C INTERIORS	C10 Interior Construction	C1010 Partitions C1020 Interior Doors C1030 Fittings
	C20 Stairs	C2010 Stair Construction C2020 Stair Finishes
	C30 Interior Finishes	C3010 Wall Finishes C3020 Floor Finishes C3030 Ceiling Finishes
D SERVICES	D10 Conveying	D1010 Elevators & Lifts *D1020 Escalators & Moving Walks* D1090 Other Conveying Systems
	D20 Plumbing	D2010 Plumbing Fixtures D2020 Domestic Water Distribution D2030 Sanitary Waste D2040 Rain Water Drainage D2090 Other Plumbing Systems
	D30 HVAC	D3010 Energy Supply D3020 Heat Generating Systems D3030 Cooling Generating Systems *D3040 Distribution Systems* D3050 Terminal & Package Units D3060 Controls and Instrumentation D3070 Systems Testing & Balancing D3090 Other HVAC Systems & Equipment
	D40 Fire Protection	D4010 Sprinklers D4020 Standpipes D4030 Fire Protection Specialties D4090 Other Fire Protection Systems
	D50 Electrical	D5010 Electrical Service & Distribution D5020 Lighting and Branch Wiring D5030 Communications & Security D5090 Other Electrical Systems
E EQUIPMENT & FURNISHING	E10 Equipment	E1010 Commercial Equipment E1020 Institutional Equipment E1030 Vehicular Equipment E1090 Other Equipment
	E20 Furnishings	E2010 Fixed Furnishings E2020 Movable Furnishings
F SPECIAL CONSTRUCTION & DEMOLITION	F10 Special Construction	F1010 Special Structures F1020 Integrated Construction F1030 Special Construction Systems F1040 Special Facilities F1050 Special Controls and Instrumentations
	F20 Selective Building Demolition	F2010 Building Elements Demolition F2020 Hazardous Components Abatement

FIG. 2 One Section of the UNIFORMAT II Classification of Building Elements (Practice E1557), Shown as a Format for Creating a WBS

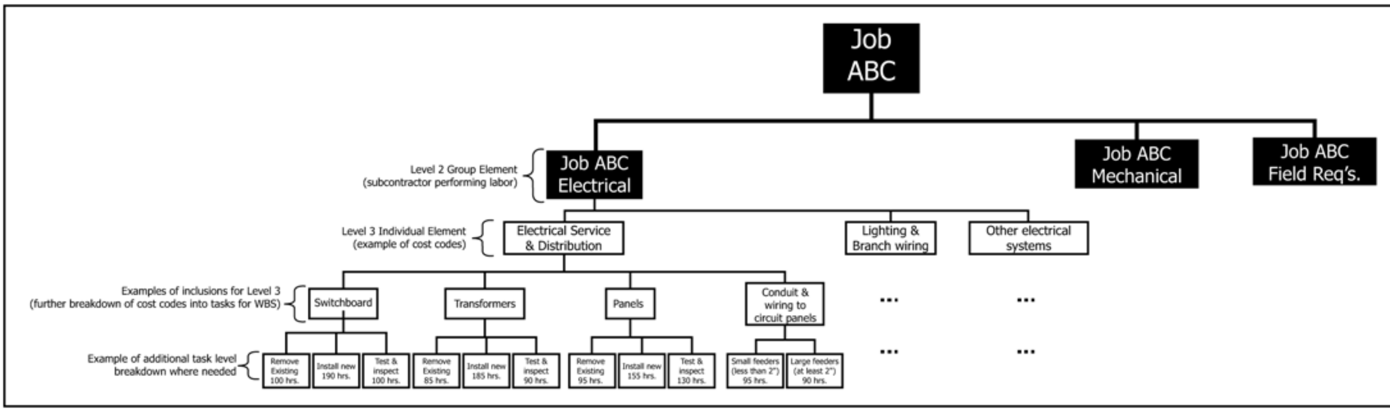


FIG. 3 Partial WBS for Electrical Subcontractor, Based on UNIFORMAT II

9.1.1 Report the CPIP, measured by observed percent complete on each task, as shown in Table 3, column 6.

9.1.1.1 Calculate observed percent complete per cost code, by summing the weighted percent complete per task item for the cost code (Eq 7).

$$Observed\%Complete_{CostCode} = \sum_{TasksforCostCode} (Observed\%Complete_{Task} \cdot BLHBTaskWeightperCostCode) \quad (7)$$

NOTE 3—For Eq 7, Observed%Complete is expressed as a percentage and can take any value between 0 and 100.

9.1.2 Report the hours expended by the labor on each cost code, as shown in Table 4, column 7.

9.1.3 Calculate current productivity per cost code[10] as the labor hours expended per observed percent of CPIP for each cost code, based on the labor hours expended and the observed percent complete per cost code (Eq 8).

$$CurrentProductivity_{CostCode} = \frac{LaborHoursExpended_{CostCode}}{Observed\%Complete_{CostCode}} \quad (8)$$

NOTE 4—Observed%Complete is expressed in whole numbers in Eq 8, taking a value between 0 and 100.

9.1.4 Calculate the productivity differential as the percent difference between the LPRP and the current productivity, for each cost code (Eq 9).

$$ProductivityDifferential_{CostCode} = \frac{(LPRP_{CostCode} - CurrentProductivity_{CostCode})}{LPRP_{CostCode}} \quad (9)$$

9.1.5 Determine the total job productivity differential by taking the weighted average of the cost code productivity differentials.

$$ProductivityDifferential_{Job} = \sum_{CostCodes} (ProductivityDifferential_{CostCode} \times BLBHCostCodeWeight) \quad (10)$$

9.1.6 Continue evaluation of LPRP on periodic basis.

10. Report

10.1 Report the productivity differential on each cost code and for the job on a Summary Sheet (Table 5), which includes all of the elements from Tables 1-4, and the productivity differential for one reporting period.

10.2 Graphically represent the productivity differential trend over time, with the 0 % line representing the LPRP.

10.2.1 When the productivity differential is above the line, interpret that the job productivity is better than planned according to the initial LPRP (Fig. 4).

10.2.2 When the productivity differential is below the line, interpret that the job productivity is worse than planned according to the initial LPRP (Fig. 4).

10.3 Plot the percent productivity differential from each JPM update on a line graph, to show the trend in the differential over time, on the job, and by cost code (Fig. 5).

11. Applications

11.1 Review productivity trends for early warning signals of deviations in the form of any gains or losses in productivity, and anomalies as shown in Fig. 6, from the productivity reference point to identify special causes. Any anomaly or deviation from the reference point is a special cause if it has any the following characteristics:[11]

11.1.1 Trends: 6 or more points in the same direction.

11.1.2 Shifts in the mean: 9 or more points in a row on one side of the mean with the rest of the points fall at the other side of the mean.

11.1.3 Extreme points: a point more than 3 standard deviations above or below the mean.

11.1.4 Alternating ups and downs (saw tooth pattern): 14 points alternating vigorously.

11.2 Missing data is a clear indication of lack of process control and requires immediate attention.

[10] Current average productivity per job can also be calculated as labor hours expended per job divided by the observed percent complete for the job. Although this calculation is not used for calculation of the productivity differential and tracking JPM, it is a by-product of the data collected for JPM. For example, using the numbers in Table 4, current average productivity for the job is 37.7 hours per observed percent of CPIP (that is, 1508 divided by 40 = 37.7; where 1508 is listed in line 60, column 7, and 40 is listed in line 60, column 6).

[11] Practice E2587 describes four signals of a shift in the process level which are suitable for manufacturing; the signals listed here are modifications which apply in construction, based on common practice of JPM.

TABLE 1 Calculation of BLHB Using UNIFORMAT II Classification and WBS

Column # → Row # ↓	1	2a	2b	3
1	(UNIFORMAT II Level 3 Individual Element) Cost Code	Tasks		BLHB
2	Electrical Service & Distribution	Main switchboard	Remove Existing Switchboard	100
3			Install Switchboard - Equip. Room 1	100
4			Install Switchboard - Equip. Room 2	90
5			Test & Inspect S. Board - Equip. Room 1	60
6			Test & Inspect S. Board - Equip. Room 2	40
7		Primary transformer	Remove Existing Transformers	85
8			Install Transformer - Equip. Room 1	95
9			Install Transformer - Equip. Room 2	90
10			Test & Inspect Transformer - Equip. Room 1	50
11			Test & Inspect Transformer - Equip. Room 2	40
12		Branch circuit panels	Remove Existing Panels	95
13			Install Panels - Equip. Room 1	80
14			Install Panel - Equip. Room 2	75
15			Test & Inspect Panels - Equip. Room 1	70
16			Test & Inspect Pane! - Equip. Room 2	60
17		Conduit & wiring to circuit panels	Small Feeders	95
18			Large Feeders	90
19	Total Budgeted Hours for Electrical Service & Distribution			1315
20	Lighting & Branch Wiring	Lighting Fixtures	Floor 1 - assemble	40
21			Floor 1 - install	95
22			Floor 2 - assemble	40
23			Floor 2 - install	95
24			Floor 3 - assemble	35
25			Floor 3 - install	80
26			Showroom track lighting - assemble	40
27			Showroom track lighting - install	80
28			Showroom sconces - assemble	25
29			Showroom sconces - install	70
30			Showroom lay-ins - assemble	65
31			Showroom lay-ins - install	90
32		Branch wiring and devices for lighting fixtures	Floor 1 - conduit	90
33			Floor 1 - wire	100
34			Floor 2 - conduit	90
35			Floor 2 - wire	100
36			Floor 3 - conduit	90
37			Floor 3 - wire	100
38			Showroom - conduit	100
39			Showroom - wire	90
40		Devices	Floor 1 - terminate	80
41			Floor 1 - trim	60
42			Floor 2 - terminate	80
43			Floor 2 - trim	80
44			Floor 3 - terminate	90
45			Floor 3 - trim	100
46			Showroom - terminate	70
47			Showroom - trim	80
48	Total Budgeted Hours for Lighting & Branch Wire			2155
49	Other Electrical Systems	Emergency generator	Equipment set	80
50			Equipment connection	90
51			Testing	20
52		UPS		50
53		Lightning and grounding protection system		90
54		Raceway system		100
55	Total Budgeted Hours for Other Electrical Systems			430
56	Site Lighting	Set poles		80
57		Wire and conduit for fixtures		100
58		Install fixtures		90
59	Total Budgeted Hours for Site Lighting			270
60	Total Budgeted Hours for Job			4170

11.3 If anomalies do not show any of the above-mentioned behaviors, such deviations (productivity gains or losses) are typically referred to as common variation due to daily events on the construction jobsite.

TABLE 2 Calculation of BLHB Task Weights per Cost Code and per Job

Column # → Row # ↓	1	2a	2b	3	4	5
1	(UNIFORMAT II Level 3 Individual Element) Cost Code	Tasks		BLHB	BLHB Task Weight per Cost Code	BLHB Task & Cost Code Weight per Job
2	Electrical Service & Distribution	Main switchboard	Remove Existing Switchboard	100	8 %	2.4 %
3			Install Switchboard - Equip. Room 1	100	8 %	2.4 %
4			Install Switchboard - Equip. Room 2	90	7 %	2.2 %
5			Test & Inspect S. Board - Equip. Room 1	60	5 %	1.4 %
6			Test & Inspect S. Board - Equip. Room 2	40	3 %	1.0 %
7		Primary transformer	Remove Existing Transformers	85	6 %	2.0 %
8			Install Transformer - Equip. Room 1	95	7 %	2.3 %
9			Install Transformer - Equip. Room 2	90	7 %	2.2 %
10			Test & Inspect Transformer - Equip. Room 1	50	4 %	1.2 %
11			Test & Inspect Transformer - Equip. Room 2	40	3 %	1.0 %
12		Branch circuit panels	Remove Existing Panels	95	7 %	2.3 %
13			Install Panels - Equip. Room 1	80	6 %	1.9 %
14			Install Panel - Equip. Room 2	75	6 %	1.8 %
15			Test & Inspect Panels - Equip. Room 1	70	5 %	1.7 %
16			Test & Inspect Panel - Equip. Room 2	60	5 %	1.4 %
17		Conduit & wiring to circuit panels	Small Feeders	95	7 %	2.3 %
18			Large Feeders	90	7 %	2.2 %
19	Total Budgeted Hours for Electrical Service & Distribution			1315	100 %	31.5 %
20	Lighting & Branch Wiring	Lighting Fixtures	Floor 1 - assemble	40	2 %	1.0 %
21			Floor 1 - install	95	4 %	2.3 %
22			Floor 2 - assemble	40	2 %	1.0 %
23			Floor 2 - install	95	4 %	2.3 %
24			Floor 3 - assemble	35	2 %	0.8 %
25			Floor 3 - install	80	4 %	1.9 %
26			Showroom track lighting - assemble	40	2 %	1.0 %
27			Showroom track lighting - install	80	4 %	1.9 %
28			Showroom sconces - assemble	25	1 %	0.6 %
29			Showroom sconces - install	70	3 %	1.7 %
30			Showroom lay-ins - assemble	65	3 %	1.6 %
31			Showroom lay-ins - install	90	4 %	2.2 %
32		Branch wiring and devices for lighting fixtures	Floor 1 - conduit	90	4 %	2.2 %
33			Floor 1 - wire	100	5 %	2.4 %
34			Floor 2 - conduit	90	4 %	2.2 %
35			Floor 2 - wire	100	5 %	2.4 %
36			Floor 3 - conduit	90	4 %	2.2 %
37			Floor 3 - wire	100	5 %	2.4 %
38			Showroom - conduit	100	5 %	2.4 %
39			Showroom - wire	90	4 %	2.2 %
40		Devices	Floor 1 - terminate	80	4 %	1.9 %
41			Floor 1 - trim	60	3 %	1.4 %
42			Floor 2 - terminate	80	4 %	1.9 %
43			Floor 2 - trim	80	4 %	1.9 %
44			Floor 3 - terminate	90	4 %	2.2 %
45			Floor 3 - trim	100	5 %	2.4 %
46			Showroom - terminate	70	3 %	1.7 %
47			Showroom - trim	80	4 %	1.9 %
48	Total Budgeted Hours for Lighting & Branch Wire			2155	100 %	51.7 %
49	Other Electrical Systems	Emergency generator	Equipment set	80	19 %	1.9 %
50			Equipment connection	90	21 %	2.2 %
51			Testing	20	5 %	0.5 %
52		UPS		50	12 %	1.2 %
53		Lighting and grounding protection system		90	21 %	2.2 %
54		Raceway system		100	23 %	2.4 %
55	Total Budgeted Hours for Other Electrical Systems			430	100 %	10.3 %
56	Site Lighting	Set poles		80	30 %	1.9 %
57		Wire and conduit for fixtures		100	37 %	2.4 %
58		Install fixtures		90	33 %	2.2 %
59	Total Budgeted Hours for Site Lighting			270	100 %	6.5 %
60	Total Budgeted Hours for Job			4170		

TABLE 3 Reporting CPIP per Task as Measured by Physical Observation of Percent Complete on Each Task

Column # → Row # ↓	1	2a	2b	3	4	5	6
1	(UNIFORMAT II Level 3 Individual Element) Cost Code	Tasks		BLHB	BLHB Task Weight per Cost Code	BLHB Task & Cost Code Weight per Job	Observed % Complete
2	Electrical Service & Distribution	Main switchboard	Remove Existing Switchboard	100	8 %	2.4 %	100 %
3			Install Switchboard - Equip. Room 1	100	8 %	2.4 %	50 %
4			Install Switchboard - Equip. Room 2	90	7 %	2.2 %	20 %
5			Test & Inspect S. Board - Equip. Room 1	60	5 %	1.4 %	0 %
6			Test & Inspect S. Board - Equip. Room 2	40	3 %	1.0 %	0 %
7		Primary transformer	Remove Existing Transformers	85	6 %	2.0 %	95 %
8			Install Transformer- Equip. Room 1	95	7 %	2.3 %	5 %
9			Install Transformer - Equip. Room 2	90	7 %	2.2 %	0 %
10			Test & Inspect Transformer - Equip. Room 1	50	4 %	1.2 %	0 %
11			Test & Inspect Transformer- Equip. Room 2	40	3 %	1.0 %	0 %
12		Branch circuit panels	Remove Existing Panels	95	7 %	2.3 %	100 %
13			Install Panels - Equip. Room 1	80	6 %	1.9 %	80 %
14			Install Pane! - Equip. Room 2	75	6 %	1.8 %	50 %
15			Test & Inspect Panels - Equip. Room 1	70	5 %	1.7 %	0 %
16			Test & Inspect Panel - Equip. Room 2	60	5 %	1.4 %	0 %
17		Conduit & wiring to circuit panels	Small Feeders	95	7 %	2.3 %	90 %
18			Large Feeders	90	7 %	2.2 %	100 %
19	Total Budgeted Hours (col. 3); Weight per Cost Code (col. 4); Weight per job (col. 5); Cost Code % complete (col. 6)			1315	100 %	31.5 %	48 %
20	Lighting & Branch Wiring	Lighting Fixtures	Floor 1 - assemble	40	2 %	1.0 %	75 %
21			Floor 1 - install	95	4 %	2.3 %	20 %
22			Floor 2 - assemble	40	2 %	1.0 %	30 %
23			Floor 2 - install	95	4 %	2.3 %	5 %
24			Floor 3 - assemble	35	2 %	0.8 %	0 %
25			Floor 3 - install	80	4 %	1.9 %	0 %
26			Showroom track lighting - assemble	40	2 %	1.0 %	15 %
27			Showroom track lighting - install	80	4 %	1.9 %	0 %
28			Showroom sconces - assemble	25	1 %	0.6 %	15 %
29			Showroom sconces - install	70	3 %	1.7 %	0 %
30			Showroom lay-ins - assemble	65	3 %	1.6 %	0 %
31			Showroom lay-ins - install	90	4 %	2.2 %	0 %
32		Branch wiring and devices for lighting fixtures	Floor 1 - conduit	90	4 %	2.2 %	75 %
33			Floor 1 - wire	100	5 %	2.4 %	25 %
34			Floor 2 - conduit	90	4 %	2.2 %	45 %
35			Floor 2 - wire	100	5 %	2.4 %	5 %
36			Floor 3 - conduit	90	4 %	2.2 %	0 %
37			Floor 3 - wire	100	5 %	2.4 %	0 %
38			Showroom - conduit	100	5 %	2.4 %	100 %
39			Showroom - wire	90	4 %	2.2 %	100 %
40		Devices	Floor 1 - terminate	80	4 %	1.9 %	25 %
41			Floor 1 - trim	60	3 %	1.4 %	0 %
42			Floor 2 - terminate	80	4 %	1.9 %	0 %
43			Floor 2 - trim	80	4 %	1.9 %	0 %
44			Floor 3 - terminate	90	4 %	2.2 %	0 %
45			Floor 3 - trim	100	5 %	2.4 %	0 %
46			Showroom - terminate	70	3 %	1.7 %	0 %
47			Showroom - trim	80	4 %	1.9 %	0 %
48	Total Budgeted Hours (col. 3); Weight per Cost Code (col. 4); Weight per job (col. 5); Cost Code % complete (col. 6)			2155	100 %	51.7 %	20 %
49	Other Electrical Systems	Emergency generator	Equipment set	80	19 %	1.9 %	100 %
50			Equipment connection	90	21 %	2.2 %	100 %
51			Testing	20	5 %	0.5 %	50 %
52		UPS		50	12 %	1.2 %	100 %
53		Grounding		90	21 %	2.2 %	100 %
54		Special Raceway		100	23 %	2.4 %	100 %
55	Total Budgeted Hours (col. 3); Weight per Cost Code (col. 4); Weight per job (col. 5); Cost Code % complete (col. 6)			430	100 %	10.3 %	98 %
56	Site Lighting	Set poles		80	30 %	1.9 %	80 %
57		Wire and conduit for fixtures		100	37 %	2.4 %	65 %
58		Install fixtures		90	33 %	2.2 %	55 %
59	Total Budgeted Hours (col. 3); Weight per Cost Code (col. 4); Weight per job (col. 5); Cost Code % complete (col. 6)			270	100 %	6.5 %	66 %
60	Total Budgeted Hours for Job (col. 3); Observed%Complete for Job (col. 6)			4170			40 %

TABLE 4 Reporting Expended Labor Hours per Cost Code

Column # → Row # ↓	1	2a	2b	3	4	5	6	7
1	(UNIFORMAT II Level 3 Individual Element) Cost Code	Tasks		BLHB	BLHB Task Weight per Cost Code	BLHB Task & Cost Code Weight per Job	Observed % Complete	Expended Labor Hours
2	Electrical Service & Distribution	Main switchboard	Remove Existing Switchboard	100	8 %	2.4 %	100 %	
3			Install Switchboard - Equip. Room 1	100	8 %	2.4 %	50 %	
4			Install Switchboard - Equip. Room 2	90	7 %	2.2 %	20 %	
5			Test & Inspect S. Board - Equip. Room 1	60	5 %	1.4 %	0 %	
6			Test & inspect S. Board - Equip. Room 2	40	3 %	1.0 %	0 %	
7		Primary transformer	Remove Existing Transformers	85	6 %	2.0 %	95 %	
8			Install Transformer- Equip. Room 1	95	7 %	2.3 %	5 %	
9			Install Transformer- Equip. Room 2	90	7 %	2.2 %	0 %	
10			Test & Inspect Transformer- Equip. Room 1	50	4 %	1.2 %	0 %	
11			Test & Inspect Transformer- Equip. Room 2	40	3 %	1.0 %	0 %	
12		Branch circuit panels	Remove Existing Panels	95	7 %	2.3 %	100 %	
13			Install Panels - Equip. Room 1	80	6 %	1.9 %	80 %	
14			Install Panel - Equip. Room 2	75	6 %	1.8 %	50 %	
15			Test & Inspect Panels - Equip. Room 1	70	5 %	1.7 %	0 %	
16			Test & inspect Panel - Equip. Room 2	60	5 %	1.4 %	0 %	
17		Conduit & wiring to circuit panels	Small Feeders	95	7 %	2.3 %	90 %	
18			Large Feeders	90	7 %	2.2 %	100 %	
19	Total Budgeted Hours (col. 3); Weight per Cost Code (col. 4); Weight per job (col. 5); Cost Code % complete (col. 6); Expended Labor Hours per Cost Code (col. 7)			1315	100 %	31.5 %	48 %	450
20	Lighting & Branch Wiring	Lighting Fixtures	Floor 1 - assemble	40	2 %	1.0 %	75 %	
21			Floor 1 - install	95	4 %	2.3 %	20 %	
22			Floor 2 - assemble	40	2 %	1.0 %	30 %	
23			Floor 2 - install	95	4 %	2.3 %	5 %	
24			Floor 3 - assemble	35	2 %	0.8 %	0 %	
25			Floor 3 - install	80	4 %	1.9 %	0 %	
26			Showroom track lighting - assemble	40	2 %	1.0 %	15 %	
27			Showroom track lighting - install	80	4 %	1.9 %	0 %	
28			Showroom sconces - assemble	25	1 %	0.6 %	15 %	
29			Showroom sconces - install	70	3 %	1.7 %	0 %	
30			Showroom lay-ins - assemble	65	3 %	1.6 %	0 %	
31			Showroom lay-ins - install	90	4 %	2.2 %	0 %	
32		Branch wiring and devices for lighting fixtures	Floor 1 - conduit	90	4 %	2.2 %	75 %	
33			Floor 1 - wire	100	5 %	2.4 %	25 %	
34			Floor 2 - conduit	90	4 %	2.2 %	45 %	
35			Floor 2 - wire	100	5 %	2.4 %	5 %	
36			Floor 3 - conduit	90	4 %	2.2 %	0 %	
37			Floor 3 - wire	100	5 %	2.4 %	0 %	
38			Showroom - conduit	100	5 %	2.4 %	100 %	
39			Showroom - wire	90	4 %	2.2 %	100 %	
40		Devices	Floor 1 - terminate	80	4 %	1.9 %	25 %	
41			Floor 1 - trim	60	3 %	1.4 %	0 %	
42			Floor 2 - terminate	80	4 %	1.9 %	0 %	
43			Floor 2 - trim	80	4 %	1.9 %	0 %	
44			Floor 3 - terminate	90	4 %	2.2 %	0 %	
45			Floor 3 - trim	100	5 %	2.4 %	0 %	
46			Showroom - terminate	70	3 %	1.7 %	0 %	
47			Showroom - trim	80	4 %	1.9 %	0 %	
48	Total Budgeted Hours (col. 3) ; Weight per Cost Code (col. 4); Weight per job (col. 5); Cost Code % complete (col. 6); Expended Labor Hours per Cost Code (col. 7)			2155	100 %	51.7 %	20 %	725
49	Other Electrical Systems	Emergency generator	Equipment set	80	19 %	1.9 %	100 %	
50			Equipment connection	90	21 %	2.2 %	100 %	
51			Testing	20	5 %	0.5 %	50 %	
52		UPS		50	12 %	1.2 %	100 %	
53		Grounding		90	21 %	2.2 %	100 %	
54		Special Raceway		100	23 %	2.4 %	100 %	
55	Total Budgeted Hours (col. 3) ; Weight per Cost Code (col. 4); Weight per job (col. 5); Cost Code % complete (col. 6); Expended Labor Hours per Cost Code (col. 7)			430	100 %	10.3 %	98 %	325
56	Site Lighting	Set poles		80	30 %	1.9 %	80 %	
57		Wire and conduit for fixtures		100	37 %	2.4 %	65 %	
58		Install fixtures		90	33 %	2.2 %	55 %	
59	Total Budgeted Hours (col. 3); Weight per Cost Code (col. 4); Weight per job (col. 5); Cost Code % complete (col. 6); Expended Labor Hours per Cost Code (col. 7)			270	100 %	6.5 %	66 %	8
60	Total Budgeted Hours for Job (col. 3); Observed%Complete for Job (col. 6); Expended Labor hours for Job (col. 7)			4170			40 %	1508

TABLE 5 JPM Summary Sheet
(with all information about the BLHB and the productivity differential (Column 8) reported for one reporting period)

Column # → Row # ↓	1	2a	2b	3	4	5	6	7	8
1	(UNIFORMAT II Level 3 Individual Element) Cost Code	Tasks		BLHB	BLHB Task Weight per Cost Code	BLHB Task & Cost Code Weight per Job	Observed % Complete	Expended Labor Hours	% Productivity Differential
2	Electrical Service & Distribution	Main switchboard	Remove Existing Switchboard	100	8 %	2.4 %	100 %		
3			Install Switchboard - Equip. Room 1	100	8 %	2.4 %	50 %		
4			Install Switchboard - Equip. Room 2	90	7 %	2.2 %	20 %		
5			Test & Inspect S. Board - Equip. Room 1	60	5 %	1.4 %	0 %		
6			Test & inspect S. Board - Equip. Room 2	40	3 %	1.0 %	0 %		
7		Primary transformer	Remove Existing Transformers	85	6 %	2.0 %	95 %		
8			Install Transformer - Equip. Room 1	95	7 %	2.3 %	5 %		
9			Install Transformer - Equip. Room 2	90	7 %	2.2 %	0 %		
10			Test & Inspect Transformer- Equip. Room 1	50	4 %	1.2 %	0 %		
11			Test & Inspect Transformer- Equip. Room 2	40	3 %	1.0 %	0 %		
12		Branch circuit panels	Remove Existing Panels	95	7 %	2.3 %	100 %		
13			Install Panels - Equip. Room 1	80	6 %				
14			Install Panel - Equip. Room 2	75	6 %	1.8 %	50 %		
15			Test & Inspect Panels - Equip. Room 1	70	5 %	1.7 %	0 %		
16			Test & Inspect Panel - Equip. Room 2	60	5 %	1.4 %	0 %		
17		Conduit & wiring to circuit panels	Small Feeders	95	7 %	2.3 %	90 %		
18			Large Feeders	90	7 %	2.2 %	100 %		
19	Total Budgeted Hours (col. 3); Weight per Cost Code (col. 4); Weight per job (col. 5); Cost Code % complete (col. 6): Expended Labor Hours per Cost Code (col. 7); % Productivity Differential per Cost Code (col. 8)			1315	100 %	31.5 %	48 %	450	28 %
20	Lighting & Branch Wiring	Lighting Fixtures	Floor 1 - assemble	40	2 %	1.0 %	75 %		
21			Floor 1 - install	95	4 %	2.3 %	20 %		
22			Floor 2 - assemble	40	2%	1.0%	30%		
23			Floor 2 - install	95	4%	2.3%	5%		
24			Floor 3 - assemble	35	2%	0.8%	0%		
25			Floor 3 - install	80	4 %	1.9 %	0 %		
26			Showroom track lighting - assemble	40	2 %	1.0 %	15 %		
27			Showroom track lighting - install	80	4 %	1.9 %	0 %		
28			Showroom sconces - assemble	25	1 %	0.6 %	15 %		
29			Showroom sconces - install	70	3 %	1.7 %	0 %		
30			Showroom lay-ins - assemble	65	3 %	1.6 %	0 %		
31			Showroom lay-ins - install	90	4 %	2.2 %	0 %		
32		Branch wiring and devices for lighting fixtures	Floor 1 - conduit	90	4 %	2.2 %	75 %		
33			Floor 1 - wire	100	5 %	2.4 %	25 %		
34			Floor 2 - conduit	90	4 %	2.2 %	45 %		
35			Floor 2 - wire	100	5 %	2.4 %	5 %		
36			Floor 3 - conduit	90	4 %	2.2 %	0 %		
37			Floor 3 - wire	100	5 %	2.4 %	0 %		
38			Showroom - conduit	100	5 %	2.4 %	100 %		
39			Showroom - wire	90	4 %	2.2 %	100 %		
40		Devices	Floor 1 - terminate	80	4 %	1.9 %	25 %		
41			Floor 1 - trim	60	3 %	1.4 %	0 %		
42			Floor 2 - terminate	80	4 %	1.9 %	0 %		
43			Floor 2 - trim	80	4 %	1.9 %	0 %		
44			Floor 3 - terminate	90	4 %	2.2 %	0 %		
45			Floor 3 - trim	100	5 %	2.4 %	0 %		
46			Showroom - terminate	70	3 %	1.7 %	0 %		
47			Showroom - trim	80	4 %	1.9 %	0 %		
48	Total Budgeted Hours (col. 3); Weight per Cost Code (col. 4); Weight per job (col. 5); Cost Code % complete (col. 6): Expended Labor Hours per Cost Code (col. 7); % Productivity Differential per Cost Code (col. 8)			2155	100 %	51.7 %	20 %	725	-71 %
49	Other Electrical Systems	Emergency generator	Equipment set	80	19 %	1.9 %	100 %		
50			Equipment connection	90	21 %	2.2 %	100 %		
51			Testing	20	5 %	0.5 %	50 %		
52		UPS		50	12 %	1.2 %	100 %		
53		Grounding		90	21 %	2.2 %	100 %		
54		Special Raceway		100	23 %	2.4 %	100 %		
55	Total Budgeted Hours (col. 3); Weight per Cost Code (col. 4); Weight per job (col. 5); Cost Code % complete (col. 6): Expended Labor Hours per Cost Code (col. 7); % Productivity Differential per Cost Code (col. 8)			430	100 %	10.3 %	98 %	325	23 %
56	Site Lighting	Set poles		80	30 %	1.9 %	80 %		
57		Wire and conduit for fixtures		100	37 %	2.4 %	65 %		
58		Install fixtures		90	33 %	2.2 %	55 %		
59	Total Budgeted Hours (col. 3); Weight per Cost Code (col. 4); Weight per job (col. 5); Cost Code % complete (col. 6): Expended Labor Hours per Cost Code (col. 7); % Productivity Differential per Cost Code (col. 8)			270	100 %	6.5 %	66 %	8	96 %
60	Total Budgeted Hours for Job (col. 3); Observed%Complete for Job (col. 6); Expended Labor hours for Job (col. 7); % Productivity Differential for Job (col. 8)			4170			40 %	1,508	-19 %

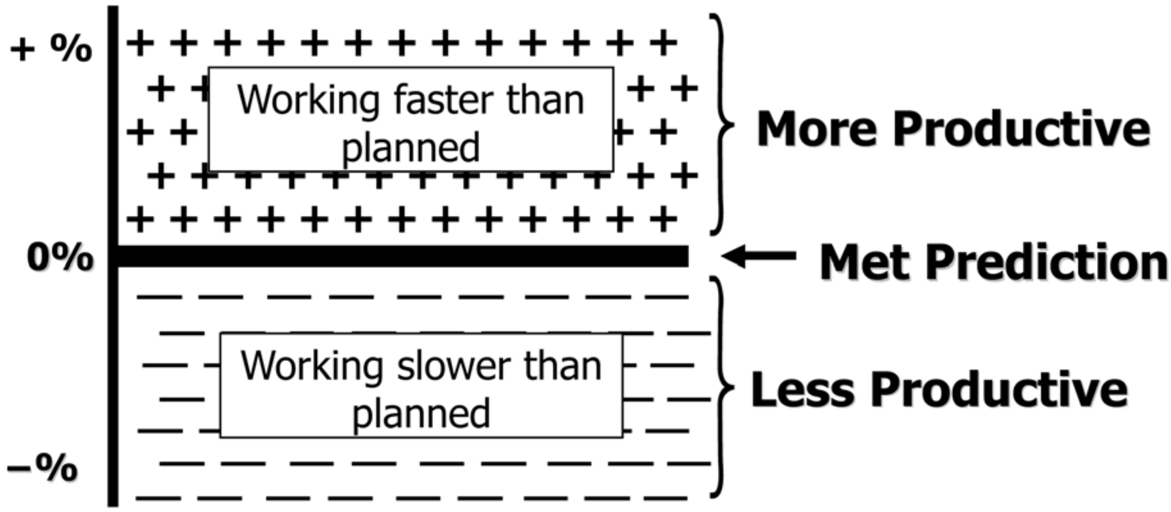
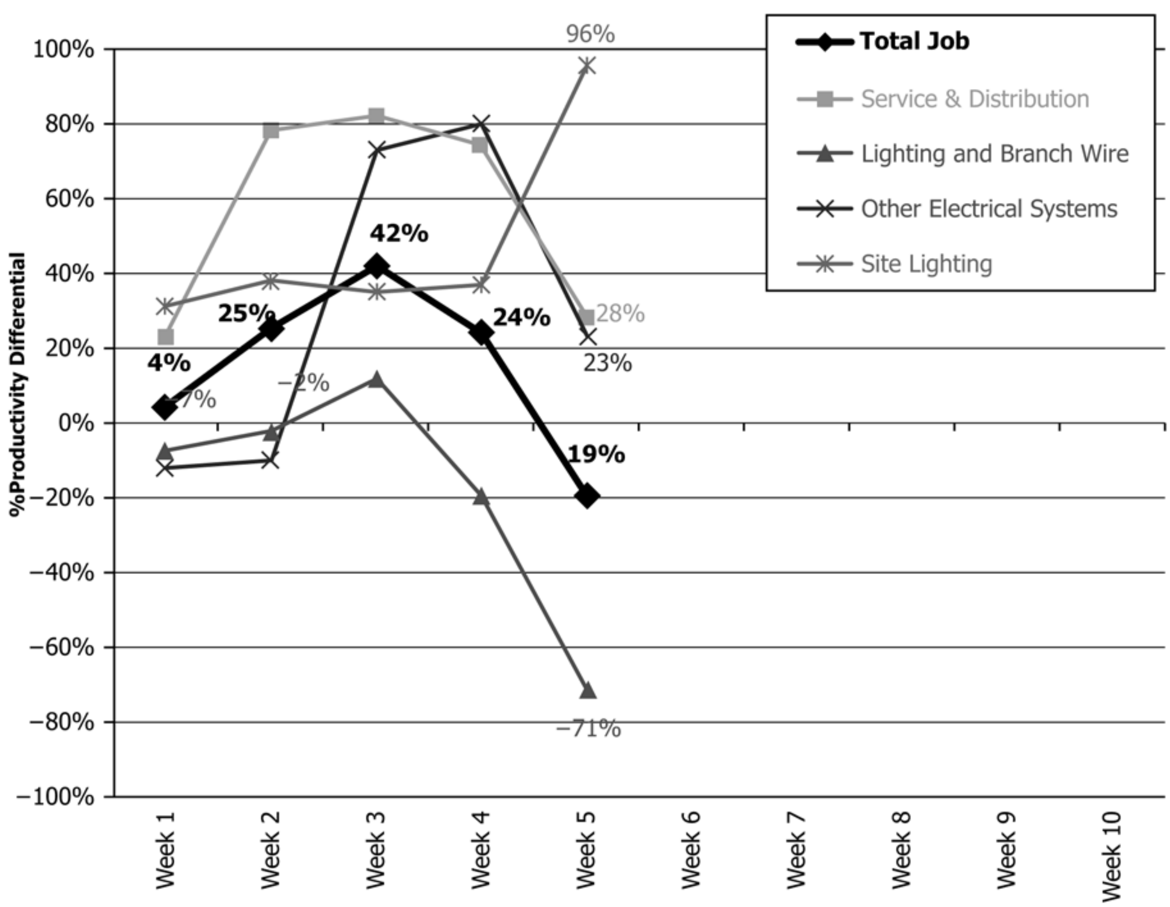


FIG. 4 JPM Graphical Output Interpretation



NOTE 1—The values for Week 5 are listed in Table 5.

FIG. 5 Plot of JPM Output (Productivity Differential Trend) for Total Job and Each Cost Code

11.4 Analyze the JPM trends for individual jobs.

11.4.1 *Total Job*—Observe the total job trend for presence of any special causes. If there are no special trends as identified in Fig. 5, then use the productivity deviation to establish if the job is ahead or behind the expected productivity reference point.

11.4.2 *Cost Code*—Observe the cost code trends following the same procedure used in 11.4.1.

11.4.3 If any special cause signals are present in the total job or the cost codes, they must be explained. The General Foreman (GF) and Project Manager (PM) collaborate to identify potential reasons of the special cause, and then develop an action plan for responding to them. If the special cause is negative (that is, a downward trend, or a significantly negative shift in the mean), the PM and GF need to identify the

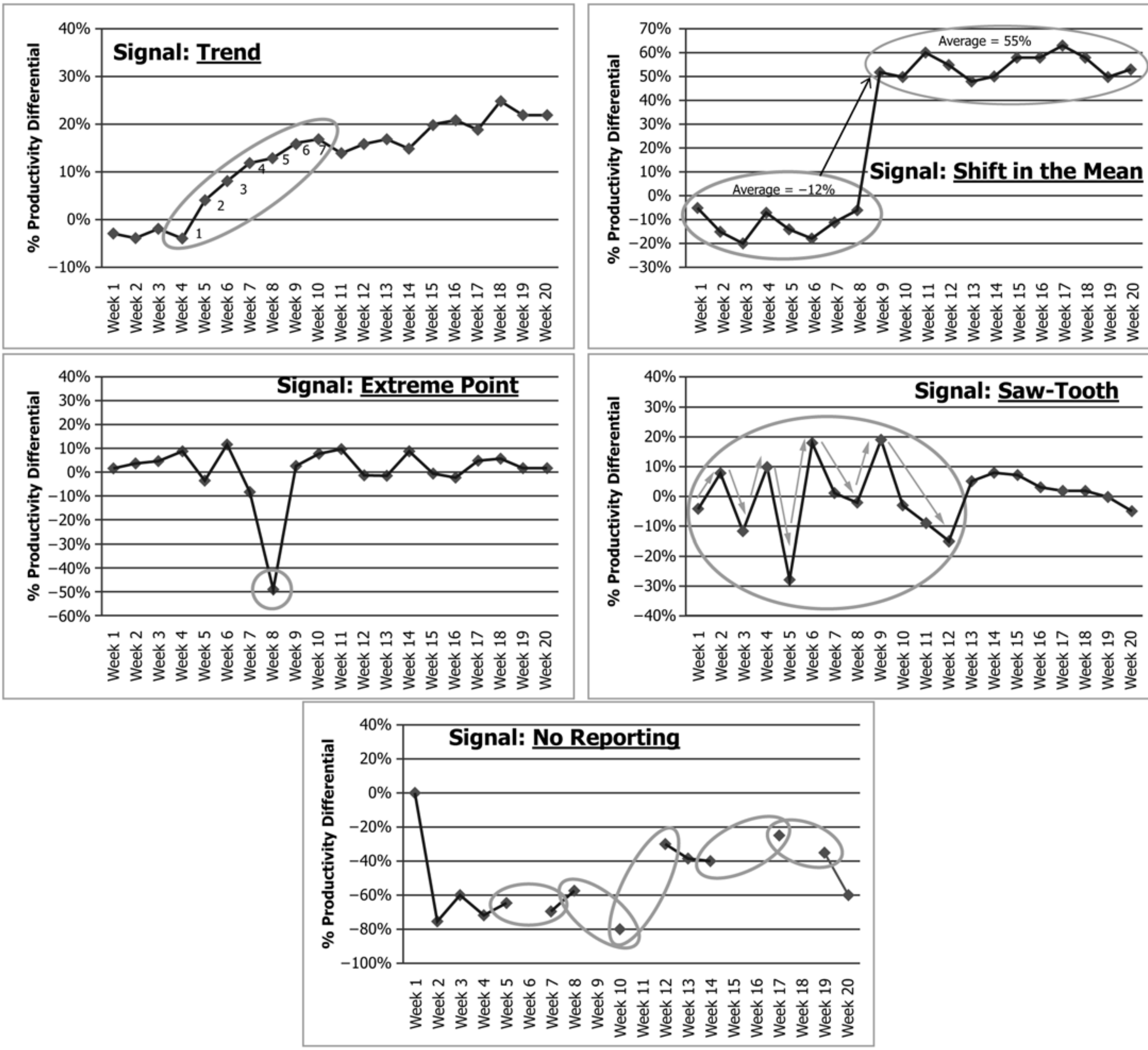


FIG. 6 Five Signals Identifiable by Trending the JPM, Indicating a Special Cause in the Productivity Differential

cause and attempt to resolve it. If the special cause is positive (that is, an upward trend or an upward shift in the mean), the PM and GF identify what positively impacted the productivity. This information can be shared within the company, or with other contractors on the same job for continuous improvement.

11.4.4 The secondary information provided by observation of the cost code trends is the impact of the cost codes on the total job behavior, based on the portion of the baseline labor hour budget in each cost code, attributed to the baseline labor hour budget for the job. Use the following steps to analyze the impact of individual cost codes on the total job behavior.

11.4.4.1 Reference the Summary Sheet (Table 5) to identify which cost codes have the highest impact on the total job, based on the $BLHB_{CostCode}$ as a portion of the $BLHB_{Job}$. The impact of cost codes with a BLHB comparatively larger than other cost codes can also be identified on the trend chart, by comparison of the cost code's behavior to the job total trend. The total job trend in Fig. 4 resembles the trends for the Service & Distribution and the Lighting & Branch Wire cost codes. Referencing the Summary Sheet in Table 5 (column 5), these two cost codes together represent 83 % of the $BLHB_{Job}$.

11.4.5 The person who analyzes the cost code trend will note the reasons for anomalies and special causes on the chart for the date of occurrence for record keeping purposes.

11.5 Review the JPM trends for a company or industry.

11.5.1 A contractor reviews the total job trend for all jobs, as shown in Fig. 7.

11.5.2 A General Contractor, Architect, Engineer, Construction Manager, or other entity managing an overall construction

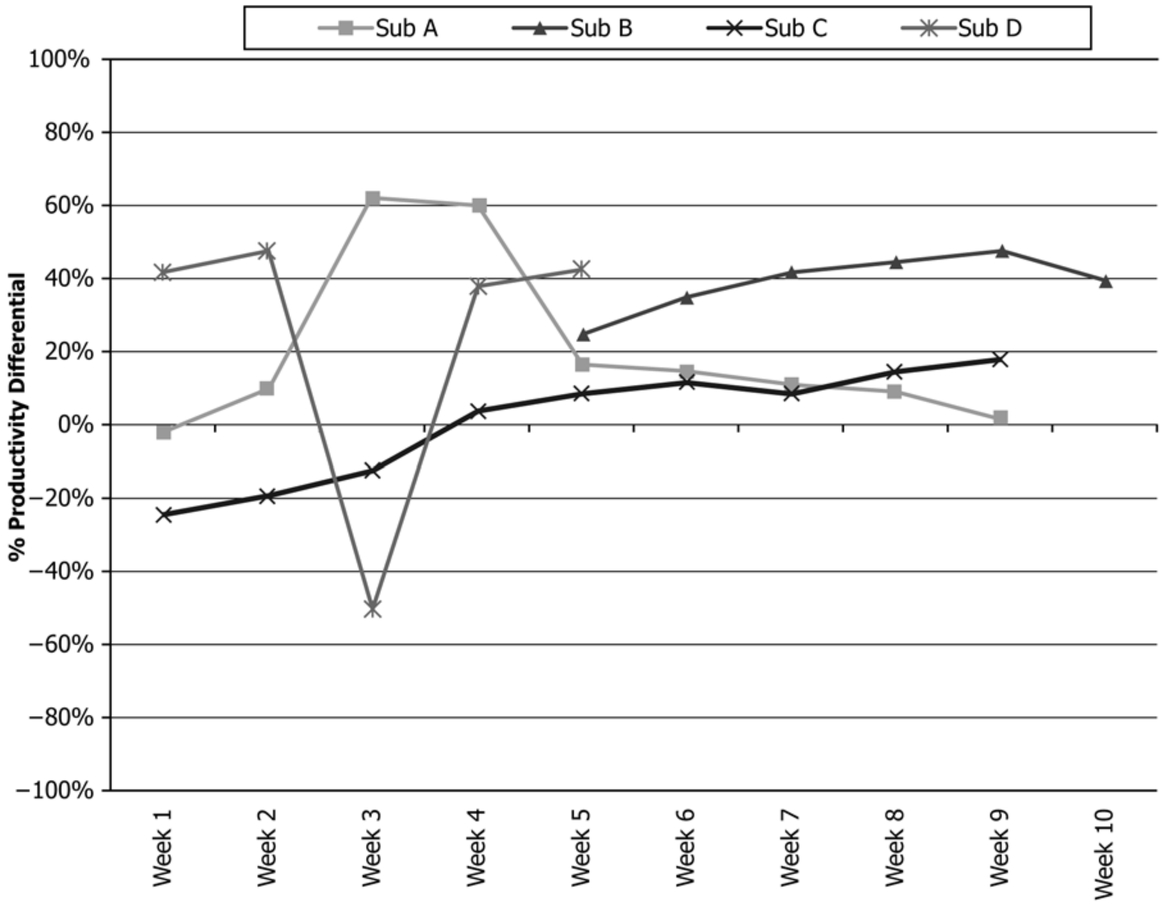


FIG. 7 Overall Company JPM Trend, Showing Individual Job Total Trends

project reviews the total job trend for all subcontractors. This would be similar to Fig. 7 with each line representing a subcontractor rather than a job.

11.5.3 All cost codes can be compared across several jobs for a company, or for the industry. For example, a cost code may do consistently well on all jobs for a company, and another cost code may be completely unpredictable. The industry can analyze cost codes for expected productivity, and identify areas for improvement and training industry-wide.

11.6 Use JPM for contract billing.

11.6.1 Use of JPM for contract billing results in a number of benefits, both for contractors and owners, including but not limited to: (*1*) increased billing accuracy; (*2*) improved cash flow; (*3*) improved gross margin; and (*4*) more reliable substantiation.

11.6.2 Appendix X1 provides an in-depth discussion of how to use JPM for contract billing along with its advantages over using other accounting methods.

11.6.3 Appendix X2 provides an approach for supplementing the JPM reports with root causes for productivity impacts.

12. Keywords

12.1 accounting; agile; agile construction; construction accounting; construction production; construction productivity measure; construction put in place; cost codes; CPIP; effectiveness; efficiency; individual productivity; job labor variance; job layout; job productivity; job productivity assurance and control; job productivity measurement; job tracking; JPAC; JPM; labor productivity; labor variation; lean; lean construction; low cost provider; observed percent complete; planning; predicting profits; predictions; process of project management; production; productivity; productivity measurement; profitability; Six Sigma in construction; SPC; SPC in construction; statistical process control; system productivity; trends; trend monitoring; value engineering; variation; variation measurement in construction; work breakdown structure

APPENDIXES

(Nonmandatory Information)

X1. USING THE JOB PRODUCTIVITY MEASUREMENT STANDARD PRACTICE FOR BILLING

X1.1 Overview

X1.1.1 Appendix X1 gives an illustration of how the JPM method can be used to improve contract billing for both the billing recipient and for the biller. For the billing recipient, the usage of observed percentage complete, which is an outcome of the JPM reporting, increases the accuracy of the received bills based on substantiation by JPM. The method is advantageous for the billing contractor because JPM requires a work breakdown structure and up-front identification of all activities on a project (including non-installation activities). Therefore, billing based on effort expended using observed percentage complete will be more closely matched to the activities occurring on the project, which results in better timing of cash flow for the billing contractor. Cash flow depends on billing, which depends on the measurement used to quantify construction-put-in-place (CPIP). The historical measurement for CPIP used for contract billing is cost-to-cost. Using this measure assumes that a direct and causal correlation exists between the percentage completion of a construction project and its incurred cost (**2**). This assumption is the basis of the accounting-based Earned Value Analysis (EVA) as well, which measures completion based on cost. However, there are activities in a project where cost is not representative of the contribution to CPIP. In addition, EVA neglects to account for many activities leading to the final assembly of the project such as:

X1.1.1.1 Planning;
X1.1.1.2 Prefabrication;
X1.1.1.3 Preassembly;
X1.1.1.4 Preparation for installation (that is, layout and benchmarks, gathering tools and equipment);
X1.1.1.5 Material handling;
X1.1.1.6 Modeling (CAD, BIM, GPS), testing, inspection, and commissioning; and
X1.1.1.7 Turnover and training.

X1.1.2 Using this practice, on the other hand, will lead to measurement and quantification of all activities performed to accomplish the final task of installation. Use of JPM will also distinguish the factors contributing to construction-put-in-place (as listed above) from the factors detracting from CPIP, such as:

X1.1.2.1 Unscheduled activities,
X1.1.2.2 Unnecessary material handling,
X1.1.2.3 Rework,
X1.1.2.4 Trade interferences, and
X1.1.2.5 Out-of-sequence work.

X1.2 Conventional Billing Methods

X1.2.1 Historically "there are two basic accounting methods available to the construction contractor for expense and revenue recognition purposes" (**3**, **4**). One method is the *cash basis of accounting*. The second method is the *accrual basis approach*. The fundamental distinction between the two methods lies in the recognition, recording, matching, and reporting time of a financial transaction (**5**). When the cash basis method is used, both revenue and expenses are recognized in the accounting period in which cash is received or remitted. Financial reporting using this method does not reflect the true financial position of a construction company, since the timing of when cash is spent or received is independent of construction put in place using the contractor's resources (**6**). The accrual basis of accounting recognizes revenue earned in the same timeframe that expenses were incurred corresponding to the resources utilized to earn the revenue. Therefore, under the accrual method it is immaterial when cash is received or remitted. Thus, under Generally Accepted Accounting Principles (GAAP), accrual accounting recognizes revenue with financial transactions in the accounting period that affixes a right of title to receive such revenue for labor, services, and materials rendered to date (**6**). Independent of the selected accounting reporting methods, there are three methods of progress billing allowed, which are discussed in the next section.

CONSTRUCTION PROGRESS BILLING METHODS

X1.2.2 Prior to 1976, construction contracts were billed using either the percentage-of- completion (POC) method, or the completed-contract-method (CCM) (**7**). Contractors using the CCM did not bill for their services on a project until the project was completed. This was problematic, especially for long-term projects where contractors would have cash outlays for months or even years before being paid for their progress. Contractors using the POC method can bill during construction progress, based on a measure of percentage complete of the project.

X1.2.3 In 1982, the Treasury Department for the first time publicly advocated that CCM not be allowed on long-term contracts except when an estimate of percentage complete was not possible (**7**). The Tax Reform Act of 1986 went further to force contractors to progress bill based on the POC method only for long-term construction contracts. This introduced yet another problem of the method for measuring POC. The Financial Accounting Standards Board, in FAS No. 56 states: "ARB 45 states that "when estimates of costs to complete and extent of progress toward completion of long-term contracts are reasonably dependable, the percentage-of-completion method is preferable" and "when lack of dependable estimates or inherent hazards cause forecasts to be doubtful, the completed-contract method is preferable." (**2**) With the advent of the JPM standard practice, this exception is no longer needed since JPM provides a regular and ongoing "dependable estimate" of POC. The difficulty in using the POC techniques lies with the ability of contractors to make reasonably accurate and quantifiable cost estimates of construction progression towards completion of the contract, and from difficulty in projecting the final gross profit with some degree of accuracy for income tax purposes (**8, 9**). Three methods are available for measurement of percentage complete (POC):

X1.2.3.1 *Cost-to-cost*, which measures POC based on costs expended to date as a portion of estimated total costs at project completion

X1.2.3.2 *Effort-expended*, which is a physical measurement of the work performed (sometimes called "physical completion").

X1.2.3.3 *Units installed*, which measures POC based on the quantity of material installed to date as a portion of the expected material in place at project completion (**10**).

COMPARISON OF CTC BILLING AND EFFORT EXPENDED BILLING USING JPM FOR POC

X1.2.4 *CTC Method:*

X1.2.4.1 Owing to current tax legislation (starting with Tax Reform Act of 1986), and because the AICPA (1993) advocates the use of the cost-to-cost (CTC) method, most Certified Public Accountants prefer the CTC technique (**7, 11, 12**). As a result, the POC method under the CTC technique is the most often applied methodology in the accounting profession when attempting to ascertain gross profits from a construction contract (**11**). As mentioned earlier, the disadvantage of the CTC method is the basic assumption of a causal relationship between the cost to date and the actual CPIP. Using CTC method for POC will most of the time underestimate the actual CPIP, negatively impacting the contractor's cash-flow and profit.

X1.2.5 *JPM Method:*

X1.2.5.1 Use of the JPM standard provides a measure for effort expended that can be used to bill percentage of complete. Using this method will result in more substantiated and accurate progress billing for the bill recipient since it is correlated to construction put in place (CPIP). It will also improve the billing for the contractor, since all of the activities identified in the work breakdown structure for JPM can be billed for, regardless of the cost incurred. This means many non-installation activities that contribute to installation can be quantified as effort expended, and if the CPIP is further in progress than the costs expended on the project (due to better-than-planned productivity), the contractor can take advantage of their productivity gain and bill for the CPIP. Use of JPM will also reduce highs and lows of the billing during project progress resulting in a more stable cash flow for both the contractor and bill recipient.

X1.3 How to Use JPM for Billing

X1.3.1 The following billing example is based on Table 5, which shows the CPIP, measured by observed percent complete for each task, and also lists the expended labor hours on each cost code. The job activities have been broken down into four cost codes: Electrical Services & Distribution, Lighting & Branch Wiring, Other Electrical Systems, and Site Lighting. The schedule of values (SOV) is created according to this breakdown, as shown in Fig. X1.1. Using JPM, the work breakdown structure (WBS) underlying these four cost codes will include all activities contributing to their completion, including layout, planning, prefabrication, inspections, and more so the percentage complete of the cost code will be a results of the percentage complete of all its associated activities. The percentage of completion of the project is measured based on the aggregate of the percentage of completion of the tasks in progress up to that point. The SOV constructs the basis for monthly billing that will be submitted as construction proceeds. The amount to bill is calculated by percentage of completion, where revenue is recorded as work progresses on this contract. The table shows the difference in billing outcome if the SOV is created based on the cost-to-cost measurement of POC or if the SOV is created based on the effort expended measurement.

X1.3.2 *A Sample Comparison of Billing Between CTC and JPM Methods:*

X1.3.2.1 Under the CTC technique, the percentage complete for each cost code is derived from dividing Costs Incurred to Date (Column D) by Estimated Total Cost (Column C), with the results showing in Column E. The amount billable is obtained from multiplying Column B by Column E to give the proportion of the selling price that is deemed to be billable based on costs expended to date, with the result shown in Column F. If JPM is being used, the observed percentage

The descriptions of work in the table below are based on the figures included in the body of Standard Practice E2691.

Schedule of Values (Summary by cost code)		Traditional Cost-to-Cost Method				JPM	
Column A	Column B	Column C	Column D	Column E	Column F	Column G	Column H
Description of Work	Selling Price (Including Overhead and Profit)	Estimated Total Cost	Costs Incurred to Date	% of Estimated Cost Incurred to Date *= (Column D / Column C)*	Amount to Bill *= Column E * Column B*	Observed % Complete	Amount to Bill *= Column G * Column B*
Electrical Service & Distribution	$ 315,000	$ 283,500	$ 107,100	37.8%	$ 119,000	48%	$ 151,200
Lighting & Branch Wiring	$ 518,000	$ 466,200	$ 80,940	17.4%	$ 89,933	20%	$ 103,600
Other Electrical Systems	$ 103,000	$ 92,700	$ 77,250	83.3%	$ 85,833	98%	$ 100,940
Site Lighting	$ 65,000	$ 58,500	$ 1,950	3.3%	$ 2,167	66%	$ 42,900
Total	**$ 1,001,000**				**$ 296,933**		**$ 398,640**

By utilizing the JPM method, the contractor in this example could bill $101,707 more than if they billed using the traditional method.

FIG. X1.1 Example of Using JPM to Bill Based on Effort Expended

complete on the cost codes is a measure of effort expended. The Observed % Complete in Column 6 from Table 5 in the standard body is listed in Column G in Fig. X1.1. Then this percentage of completion is used to calculate the amount to bill by multiplying Column B by Column G, using the percentage of work complete rather than percentage of contract cost incurred to determine the proportion of the selling price that can be billed. The result is listed in Column H. JPM identifies CPIP based on labor effort expended, and the SOV billing is constructed based on this measure of CPIP.

X1.3.2.2 In Fig. X1.1, the contractor bills $296,933 under the CTC method and $398,640 using JPM. The $101,707 additional billed amount is the result of a productive project, since the CPIP is greater than the costs expended for the work. The Schedule of Values report reflects the actual progress of the construction job and connects to CPIP. Therefore, the JPM increases the billing accuracy to match more closely to effort expended on the project. Another example based on real project data is given below to further demonstrate the connection that JPM provides between billing and CPIP. Column B in Fig. X1.1 represents the total contract price for the project. Each task has an independent selling price listed, which includes the overhead and profit for the task listed. Column C is estimated total cost for each task. For example, the contractor in Fig. X1.1 estimates site lighting will cost $58,500. Column D represents the total cost incurred to date, meaning the task of lighting and branch wiring has cost the contractor $80,940 thus far. As the project progresses, we would expect to see this number rise as more money is spent on this task. Column E is a ratio comparing the estimated costs (Column C) to the cost incurred to date (Column D). When Column D is divided by Column C, we calculate the percentage of estimated costs incurred to date. Since the traditional cost-to-cost method utilizes the percentage of estimated cost incurred to date for billing, this number must be multiplied by the selling price to calculate the amount to bill, which is highlighted in Column F. Column G is the observed percent complete. Observed percent complete indicates how far the project or individual task is to completion. Based on observed percent complete, one can assume that the task of other electrical systems is 98 % complete. Column H simply uses observed percent complete to calculate the amount to be billed by the contractor. When the observed percent complete is multiplied by the total contract value, we calculate the amount to bill utilizing JPM.

X1.3.3 *A Case Study Comparison of Billing Between CTC and JPM Methods:*

X1.3.3.1 Six months of data, including revenue earned, costs incurred, observed percentage complete, and job productivity differential based on JPM, from a real construction project are used in this example to show the difference between using the cost-to-cost method and the effort expended method using JPM. Fig. X1.2 shows the data used for calculations and the source or equation used for each column of data. The method used in X1.3.2 was applied here, and the results are shown in Section X1.4

X1.3.3.2 Fig. X1.2 also shows the calculation of the job-to-date gross profit margin in Column I. The Construction Financial Management Association (CFMA) defines gross profit as the difference between contract price and contract cost. In Fig. X1.2, this contract price is represented in Column H, because it is revenue to date for the contractor. The contract cost for Fig. X1.2 is shown in Column C. Percentage of gross profit margin is calculated by dividing gross profit by the amount that has been billed to date.

X1.4 Results

X1.4.1 *Increase Billing Accuracy and Relevance to CPIP:*

X1.4.1.1 Fig. X1.3 shows the comparison of the revenue earned to date using the CTC and JPM methods, based on the case example from X1.3.3 and values in Fig. X1.2. The values plotted are from Fig. X1.2 column E for the CTC method and column H for the JPM method.

X1.4.1.2 Fig. X1.4 lists the reported weekly job productivity differential values resulting from JPM usage on the project. These values are used in Fig. X1.5. Fig. X1.4 shows the labor productivity differential on the same project measured using JPM. In the beginning of this project, the productivity is lower than the labor productivity reference point. However, as the project progresses in time and uses JPM to monitor productivity, the labor productivity improves, which also correlates to the revenue earned to date. In August, since the labor is more productive than planned, the revenue earned based on the JPM method is more than that earned using the

	Project Data			Cost-to-Cost Method			JPM Method		
	Column A	Column B	Column C	Column D	Column E	Column F	Column G	Column H	Column I
	Selling Price (Including Overhead and Profit)	Estimated Total Cost	Costs Incurred to Date	% of Estimated Cost Incurred to Date = *Column C/ Column B*	Amount to Bill = *Column A * Column D*	Job-to-Date Gross Profit Margin** (%) = *(Column E - Column C)/ Column E*	Observed % Complete *(from JPM)*	Amount to Bill = *Column A * Column G*	Job-to-Date Gross Profit Margin** (%) = *(Column H - Column C)/ Column H*
Mar-10	$ 2,798,428	$ 2,609,450	$ 281,821	10.8%	$ 302,230	6.8%	10.1%	$ 282,641	0.3%
Apr-10	$ 2,798,428	$ 2,609,450	$ 341,838	13.1%	$ 366,594	6.8%	14.2%	$ 397,377	14.0%
May-10	$ 2,832,439	$ 2,609,450	$ 417,512	16.0%	$ 453,190	7.9%	18.0%	$ 509,839	18.1%
Jun-10	$ 2,832,439	$ 2,609,450	$ 438,388	16.8%	$ 475,850	7.9%	18.7%	$ 529,666	17.2%
Jul-10	$ 2,832,439	$ 2,609,450	$ 594,955	22.8%	$ 645,796	7.9%	26.7%	$ 756,261	21.3%
Aug-10	$ 2,832,439	$ 2,609,450	$ 879,385	33.7%	$ 954,532	7.9%	37.4%	$ 1,059,332	17.0%

CFMA Defines Gross Profit Margin as **Contract Price - Contract Cost; (Ref. #9)

FIG. X1.2 Calculation of Revenue Earned to Date for Fig. X1.3 and Gross Margin for Fig. X1.6

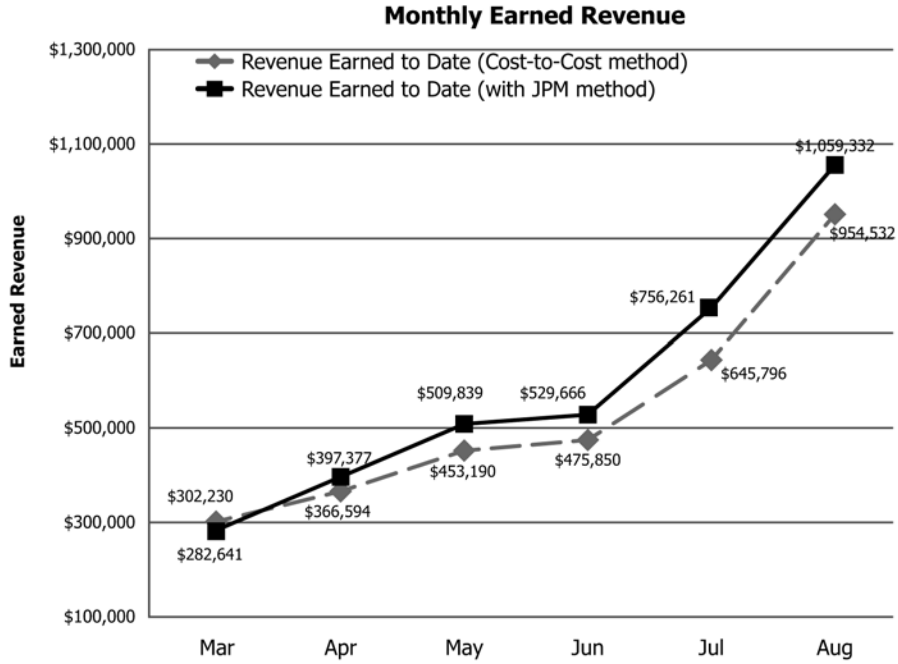


FIG. X1.3 Revenue Earned to Date Under CTC and JPM Method

Week Ending	Job Productivity Differential	Week Ending	Job Productivity Differential
3/12/2010	−22%	6/4/2010	19%
3/19/2010	−42%	6/11/2010	20%
3/26/2010	−7%	6/18/2010	23%
4/2/2010	−6%	6/25/2010	23%
4/9/2010	−16%	7/2/2010	18%
4/16/2010	−16%	7/9/2010	12%
4/23/2010	−16%	7/16/2010	21%
4/30/2010	−17%	7/23/2010	25%
5/7/2010	17%	7/30/2010	20%
5/14/2010	12%	8/6/2010	27%
5/21/2010	15%	8/13/2010	23%
5/28/2010	13%	8/20/2010	20%
		8/27/2010	34%

FIG. X1.4 Productivity Differential shown in Fig. X1.5

traditional CTC method, since there is more CPIP than labor cost expended for the same timeframe. This example shows how using JPM for measuring progress used to calculate earned revenue can lead to more accurate billing that is based on CPIP.

X1.4.2 *Improve Cash Flow by Advancing the Timeline for Billing:*

X1.4.2.1 In the first example in X1.3.2, the CTC method cannot provide evidence of incurred cost to substantiate the additional $101,707 additional amount that is billed using the JPM POC technique in Fig. X1.1. The difference of $101,707 will be collected at the end of the job with a negative impact on the contractor's cash flow. In other words, billing according to CTC method delays the schedule of cash collection.

X1.4.3 *Improve Gross Margin by Using JPM for POC:*

X1.4.3.1 The measurement used to earn revenue also impacts the gross margin collected on a project. Eq X1.1 below shows the calculation for gross margin on a project, which is based on revenue earned to date and actual costs incurred. The earned revenue can be measured with CTC, units installed, or effort expended. If the JPM is used, effort expended can be used to calculate earned revenue based on the technique listed in Section X1.3.

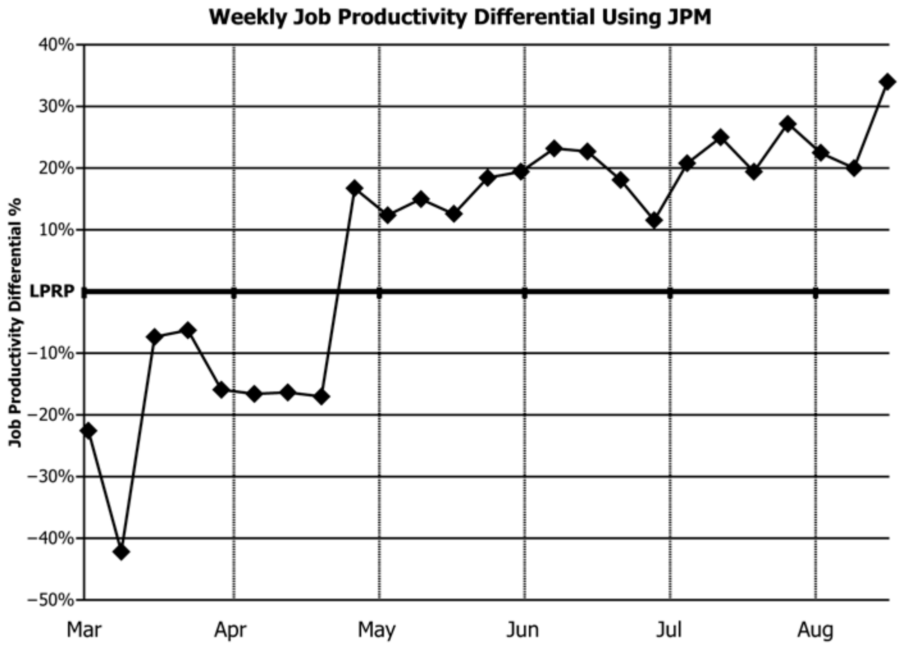


FIG. X1.5 Trend of Job Productivity Differential

$$Gross\ Margin\ \% = \frac{Revenue\ Earned\ to\ Date - Actual\ Cost}{Revenue\ Earned\ to\ Date} \times 100\,\% \quad (X1.1)$$

X1.4.3.2 The actual cost remains the same using any method, while revenue earned to date is the varying factor. When the labor is more productive than the LPRP, it means that the contractor was able to finish more work with less labor costs. In Fig. X1.6 below, the gross margin is shown as the results of using both the CTC and JPM methods, with the data from Fig. X1.2. The CTC method (data from Fig. X1.2, Column F), shows the gross margin keeps a linear pattern, since costs are expended linearly each month by the contractor; the gross margin calculated with the JPM method (data from Fig. X1.2, Column I) is higher than the gross margin measured using CTC because the contractor was accomplishing more CPIP each month than the job costs to date measured for each month.

X1.4.4 *Reliable Substantiation for Recipient of the Construction Billing:*

X1.4.4.1 Contractor payment applications for billing must be substantiated with evidence for the proportion of the contract that is billed. Applying the JPM POC technique for

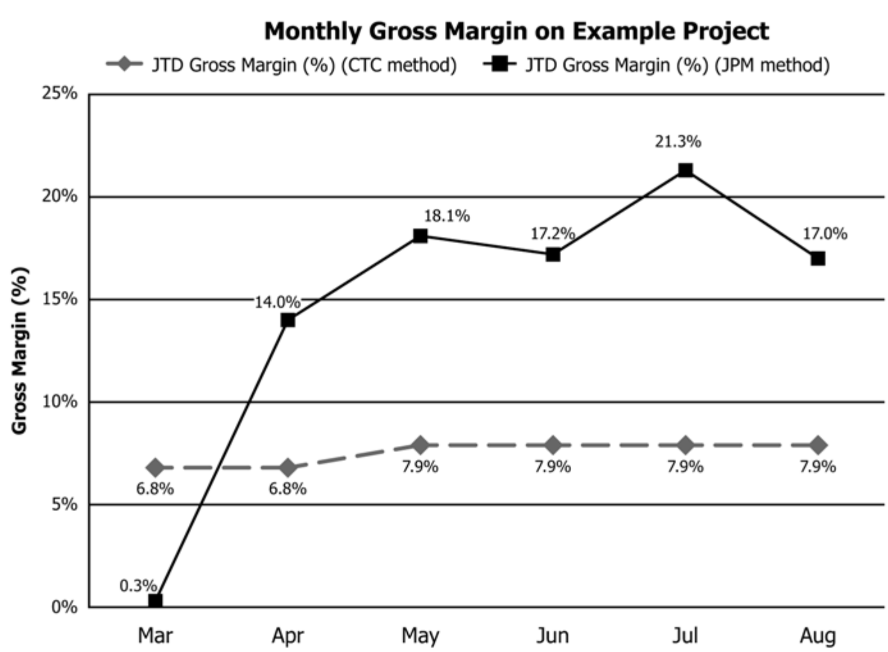


FIG. X1.6 Comparison of Gross Margin with CTC and JPM Method billing, the contractor can show the JPM summary sheet as substantiation for percentage of the contract revenue being billed at any time, which lists the percentage complete for each task.

X1.4.5 *Reduce Clutter on the Jobsite by Using JPM:*

X1.4.5.1 Contractors front load their billing on a project by billing as much cost as possible early on in the project. They do this to ensure cash flow early on that is needed to fund up-front activities in the project that may not have significant costs associated with them, and for the lack of certainty of payment as the project progresses. To do this, the contractors must incur costs to substantiate the billing, so they purchase material and tools that may not be needed until much later in the project. The excessive material and tools on the jobsite is one of the main contributors to productivity loss due to unnecessary movement and storage. This further leads to clutter and an unsafe work environment. By contrast, there is no need to incur costs up front for the purpose of billing under the JPM POC technique because the amount to bill is based on true CPIP and any activities contributing to it early on in the project can be billed for.

X1.5 Summary

X1.5.1 JPM can be used to improve billing in several ways. Relying on the preferred method of percentage-of-completion (POC) for progress billing, it provides a measure of effort expended that is related to the CPIP of the project. Without the use of JPM, contractors must use the cost to cost or units installed methods to quantify POC, which assume a direct correlation between cost and CPIP. This assumption is flawed since the CPIP is independent of costs or materials installed, rather it depends on the difficulty of installation and the timeline of activities performed on the project.

X1.5.2 The JPM can be used for billing by taking the observed percentage complete reported regularly from the project and using it as the quantification of POC. This can be used to calculate the earned revenue on the project, by multiplying the percentage complete by the contract amount. The method reduces the effort to bill, provides substantiation for the amount billed, and advances the timeline of cash flow for the job, potentially reducing the resulting cost of capital a contractor incurs for not having the cash available earlier.

X1.5.3 Overall, billing based on JPM POC technique helps a contractor to improve the financial performance in the revenue, cash flow, and gross profit.

X2. ENHANCING USE OF JOB PRODUCTIVITY MEASUREMENT STANDARD PRACTICE WITH COMMON CAUSE VARIATION MEASUREMENT

X2.1 Overview

X2.1.1 This appendix gives an instructional guideline of how to enhance JPM's capability of identifying and reporting productivity variation and its causes during the project progress. By making the root causes of common cause variation visible, the user of JPM is able to reduce variation in job productivity. Daily small and insignificant work-flow stoppages are known to the workers at the point of installation. Due to its small impact on the project productivity variation, each individual common cause of variation cannot be investigated unless the cumulative impact is measured. Small and sometimes insignificant work stoppage happens daily on a jobsite; these issues may be invisible to the project managers and superintendents, but they are very much part of the trades' daily work area negotiations, which often go untracked and unmeasured until their impact on the productivity change becomes significant. Once this occurs, it is impossible to make up the lost scheduled time of the crew and the overall project plan may suffer. To avoid having the common causes of variation become special causes, their cumulative impact on the project has to be measured, tracked and subsequently acted upon at the appropriate level of escalation. The results of the common cause reports are compared with the JPM reporting on a regular basis to review common and special cause variation simultaneously. To measure and track the common causes of variation, the quantitative scheduled activities of each person working on the jobsite are established and the deviations from those scheduled activities are measured on a daily basis.

X2.2 Data Collection

X2.2.1 *Identify Obstacle Reason Codes for a Job:*

X2.2.1.1 In every job, there are some common reasons why tasks are not able to be completed as scheduled on a specific day. Each job should identify the top 8 to 12 most likely reasons for obstacles preventing completion of scheduled work on the job. These obstacles will become "reason codes" and will be used on that job's short term schedule evaluation form. Obstacle reason codes should be customized to each job and even for individual crews or work phases within the job.

X2.2.2 *Pull Work from the Project Plan:*

X2.2.2.1 The project plan identifies activities that will be completed during the entire project. The first step to preparing for common cause variation measurement is to pull a "Three-Week Look Ahead" plan from the large scale project plan. This is the portion of the project plan that is expected to occur in the next three weeks.

X2.2.3 *Schedule Short Interval Tasks:*

X2.2.3.1 Using the Three-Week Look Ahead plan, the foreman schedules detailed and specific tasks that are expected to occur in the next three days. If a Three-Week Look Ahead plan is not available to the foreman or does not exist for the job, the foreman should schedule the tasks to the best of his ability and knowledge about the project. The tasks should be specific enough to describe just the portion of the work that should be completed in one day. If the daily scheduled task is part of an overall task that requires multiple days to complete, the short interval schedule is used to describe how much of that task is to be completed in one day. The tasks may be quantified in terms of installation quantities (that is, number of linear feet, number of hangars) or in terms of area (that is, number of rooms to be completed, number of gridlines) or in terms of non-installation activities (that is, unload one truck, create as-builts for last week's installation). The scheduled task needs a quantifiable and measurable completion goal for each day so it can be evaluated daily for completion and obstacle impacts. The short term schedule should be done at the beginning of each day. A completed short term scheduling form should be distributed to each crew worker at the beginning of each day. The schedule should answer in detail the following five questions for each of the subsequent three days:

(1) What tasks need to be done?

(2) What quantity of each task should be done?

(3) How many hours does the crew need to complete each task?

(4) Do the workers have all the material they need to complete each task?

(5) Are the tools required for each task in operational form and in place?

An example short interval scheduling form is shown in Fig. X2.1.

X2.2.4 *Evaluate Actual Tasks Completed to Scheduled Tasks:*

X2.2.4.1 At the end of each day, the foreman should review the short interval schedule for that day, and evaluate the result of work that was actually completed, with feedback from the working crews. The review should track obstacles, not production or productivity. The body of this standard is used for job productivity measurement and evaluation (see X2.3.4 for how the standard is used in conjunction with this appendix). The feedback data should come from a source as close to the installer as possible. The evaluation section of the schedule should answer the following questions for each task that was originally scheduled for the current day:

(1) What percentage of the task was actually completed that day?

Short Interval Scheduling Form

Job:
Foreman:

Date:_________________

Schedule		
Scheduled Task	Quantity	Scheduled Hours

Date:_________________

Schedule		
Scheduled Task	Quantity	Scheduled Hours

Date:_________________

Schedule		
Scheduled Task	Quantity	Scheduled Hours

FIG. X2.1 Sample Short Interval Scheduling Form

(2) What obstacles prevented the workers from completing the task as scheduled using the reason codes established at the beginning of the job?

(3) How many hours were not worked that were scheduled to be worked for this task?

In addition, the foreman should list tasks that actually occurred that were not scheduled to occur that day. These may be tasks that were able to be pulled ahead of schedule because the crew was not able to complete the day's scheduled tasks; or they may be tasks that were pulled ahead of schedule because all of the scheduled tasks were completed during the day with available time remaining; or they may be tasks that were not planned to be completed at all, but were required due to a project plan change. A completed short interval schedule review should be given to the project manager at the end of each day. An example of the evaluation section of the short interval schedule is shown in Fig. X2.2.

X2.2.5 *Prepare New Short Interval Schedule:*

X2.2.5.1 A new short interval schedule should be completed at the beginning of every day. Two of the upcoming three days had already been included on the previous day's short interval schedule, but these days will still need to be rewritten on a new schedule form. Occasionally the schedule for those two days will remain the same and will simply need to just be rewritten. However, most of the time the tasks scheduled for those days will change based on the unplanned obstacles to the scheduled tasks evaluated and reviews from the prior day.

X2.3 Data Analysis

X2.3.1 *Create Pareto Chart:*

X2.3.1.1 The Pareto principle is a recommended approach in statistical process control for managing and removing common cause variation (**13**). A Pareto chart should be created at the end of each week that compiles the obstacle reason codes for each job, both by the frequency of occurrence and by the impact in terms of hours not worked as scheduled (HNWAS). An example Pareto chart is shown in Fig. X2.3. The Pareto chart can also be used to evaluate the cumulative obstacles for the entire project.

X2.3.2 *Eliminate the Top Twenty Percent:*

X2.3.2.1 The Pareto principle of "the vital few and the trivial many" is used to evaluate the vital few obstacle categories, typically approximately 20 % of the total number of categories, which should contribute to approximately 80 % of the impact. The top twenty percent of the reason codes should be evaluated and eliminated as much as possible. Not every obstacle can be avoided, but the aggregate reason code categorization helps point out the common obstacles that can be addressed systematically rather than trying to resolve every individual occurrence.

X2.3.3 *Reduce Common Cause Variation Across Jobs:*

X2.3.3.1 Once the common causes for variation in the schedules across the jobs are identified and made visible, the variation can then be addressed at an elevated level across the company using system design principles. Visibility of common causes of variation across jobs, types of work, or common activities can be done by working with project managers, warehouse managers, distributors, and other contractors to devise solutions that will be mutually beneficial to all stakeholders.

Short Interval Scheduling Form

Job:
Foreman:

Date: ________________

Schedule			Evaluate			
Scheduled Task	Quantity	Scheduled Hours	% Complete	Reason Code if <100%	Hours Not Worked as Scheduled	Notes

Additional Tasks Done (Not Scheduled)	Hours

Reason Codes
1. Waiting for Material
2. Waiting for Tools or Equipment
3. Waiting for Equipment Repairs
4. Rework (due to design, prefab, or field errors)
5. Weather
6. Work Place Changes
7. Waiting on Permits
8. Waiting for Instructions
9. Manpower shortage
10. Waiting for other Subs
11. Other

FIG. X2.2 Short Interval Scheduling Form with Evaluation Section

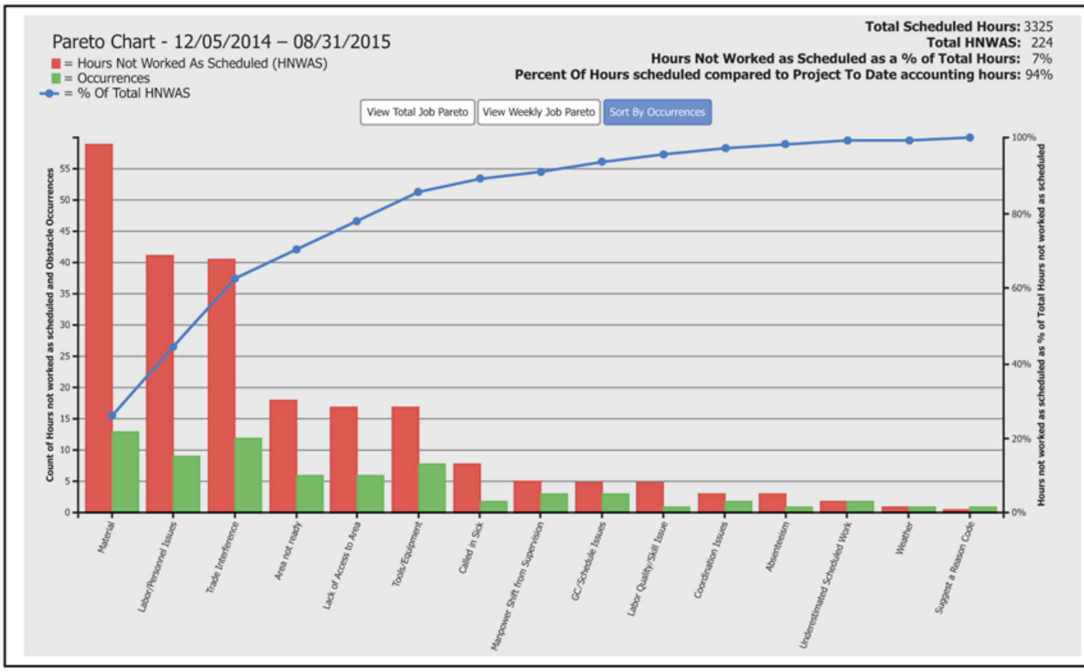


FIG. X2.3 Example Pareto Chart

X2.3.4 *Connect Common Cause Variation with JPM:*

X2.3.4.1 *Review the JPM:*

(1) In order to make visible the connection between the common cause variation and the JPM, review the total job productivity differential trend chart for a job, as shown in Fig. X2.4 (see Section 11 in the body of this standard for explanation). The productivity trend on this job was increasing for five weeks in a row (which is a special cause as explained in Section 11. Then the productivity differential began to decrease for three weeks in a row.

X2.3.4.2 *Investigate Cost Code JPM:*

(1) Fig. X2.5 shows the JPM procedure being followed, by investigating the cost codes to find out what might have caused this trend. The cost code review shows that several cost codes were impacted during the last few weeks of tracking, including Mobilization, Demolition, Conduit, Wire, Devices and Lighting. If more than one or two cost codes show the same trend, it indicates that there is a systemic problem on the jobsite that is probably the result of common causes of variation. By investigating and segregating the reasons why the daily scheduled work could not be completed, it became clear that there were coordination problems that were causing hours to go worked not as scheduled.

X2.3.4.3 *Compare to Pareto Chart:*

(1) The JPM cost code review compliments the Pareto Chart of the reasons why the scheduled work for the crews could not be completed for the same timeframe that the JPM was showing a downward trend. In this case, when it became

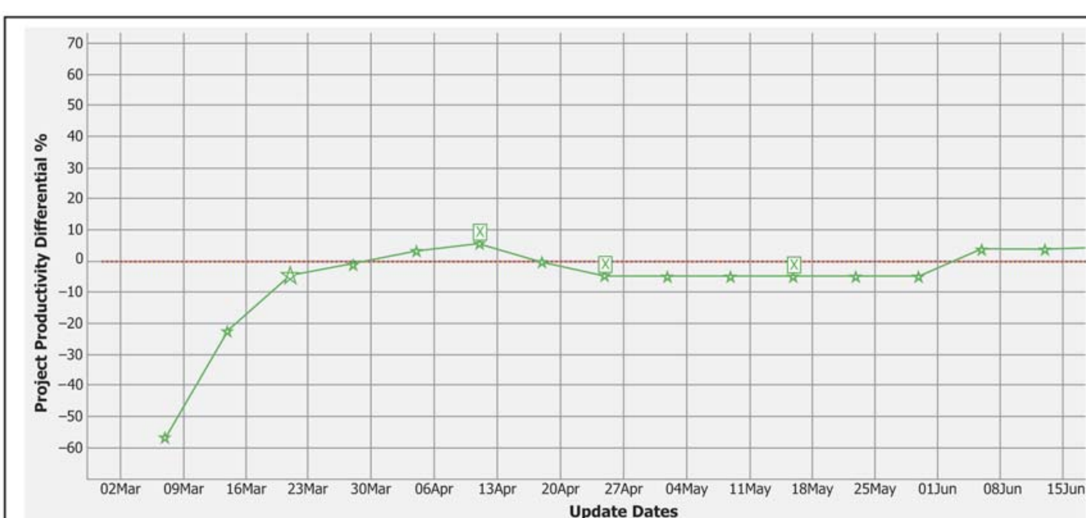


FIG. X2.4 Example JPM Trend for a Job

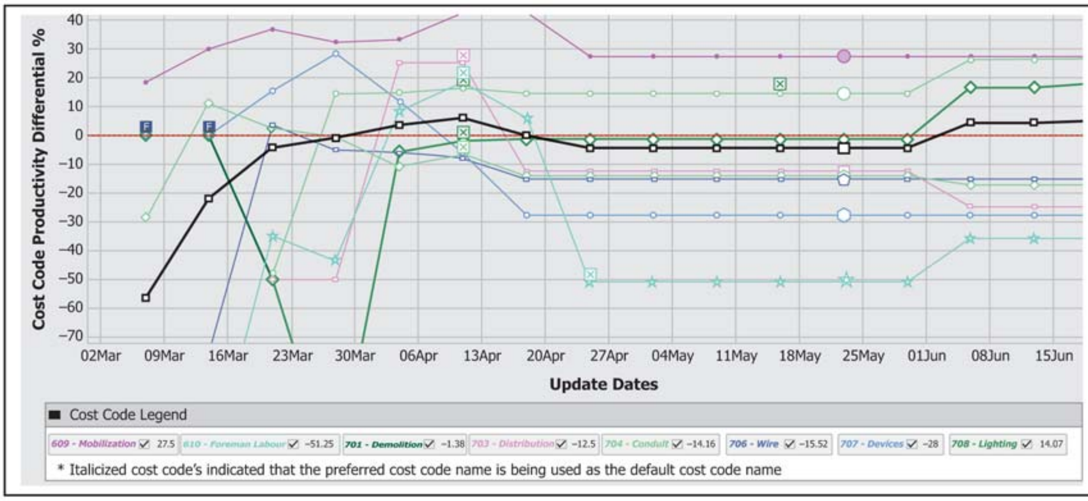


FIG. X2.5 Example JPM Segregated by Cost Codes for a Job

clear that the obstacles to completing work as scheduled were Material, labor/personnel issues and trade interference, the issue could be easily addressed. Once the coordination issues were resolved on the jobsite, the JPM for the job began to improve significantly.

X2.3.5 *Repeat the Process:*

X2.3.5.1 The entire process should be repeated on a continual basis, from the short term scheduling on a daily basis, to the analysis and productivity improvement on a weekly basis. This will address the changing common cause variation and will reduce it in order to improve productivity.

X2.4 Summary

X2.4.1 A process is needed to provide constant feedback from the point of installation on any issues or obstacles that are preventing the crew or trade from completing their scheduled activities, as they are looking out on the short term. This direct feedback is typically provided through direct observation, which is limited to physical presence of an observer onsite. Getting quantitative feedback on the common causes of variation on the jobsite is the only way that the project manager, contractor owner, other trades, and the project team can respond, resolve and reduce common cause variation on individual projects and across projects within a company.

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