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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

E2166 Practice for Organizing and Managing Building Data

E2587 Practice for Use of Control Charts in Statistical Process Control

3. Terminology

3.1 *Definitions*—For definition of terms used in this practice, refer to Terminology E631 and Terminology E833.

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.

[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.

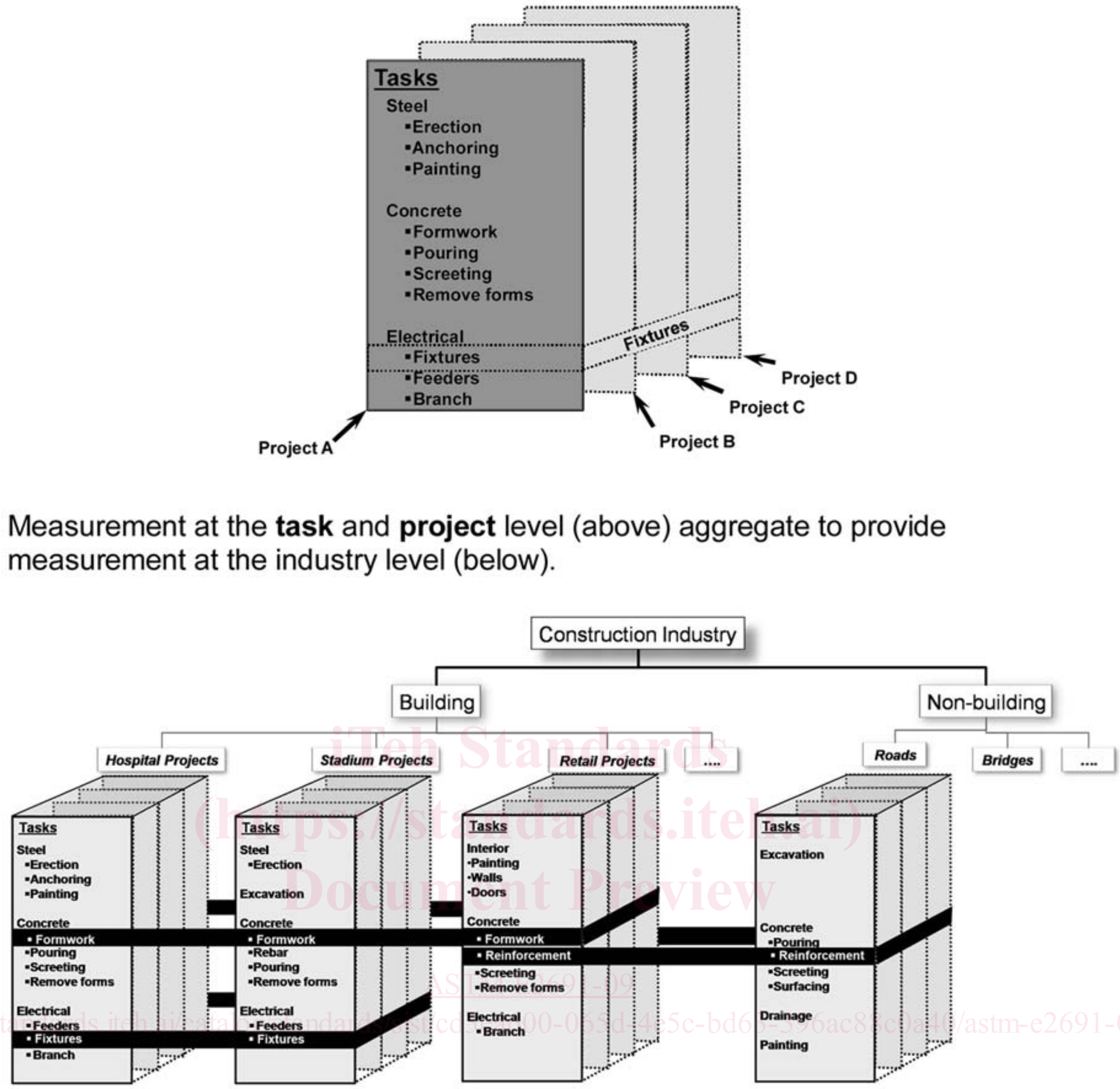
Tasks
Steel
▪Erection
▪Anchoring
▪Painting
Concrete
▪Formwork
▪Pouring
▪Screeting
▪Remove forms
Electrical
▪Fixtures
▪Feeders
▪Branch
Fixtures
Project A
Project B
Project C
Project D
Measurement at the **task** and **project** level (above) aggregate to provide measurement at the industry level (below).
Construction Industry
Building
Non-building
Hospital Projects
Stadium Projects
Retail Projects
....
Roads
Bridges
....
Tasks
Steel
▪Erection
▪Anchoring
▪Painting
Concrete
▪ Formwork
▪Pouring
▪Screeting
▪Remove forms
Electrical
▪Feeders
▪ Fixtures
▪Branch
Tasks
Steel
▪Erection
Excavation
Concrete
▪ Formwork
▪Rebar
▪Pouring
▪Remove forms
Electrical
▪Feeders
▪ Fixtures
Tasks
Interior
▪Painting
▪Walls
▪Doors
Concrete
▪ Formwork
▪ Reinforcement
▪Screeting
▪Remove forms
Electrical
▪Branch
Tasks
Excavation
Concrete
▪Pouring
▪ Reinforcement
▪Screeting
▪Surfacing
Drainage
Painting

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

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[4] 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.[5]

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 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.[6] 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. 2, 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.[7]

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:

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

[4] 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.

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

[6] 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.

[7] *R.S. Means Building Construction Cost Data 2009*, 67th edition, Reed Construction Data: Kingston, MA.

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 & FURNISHINGS	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 Instrumentation
	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

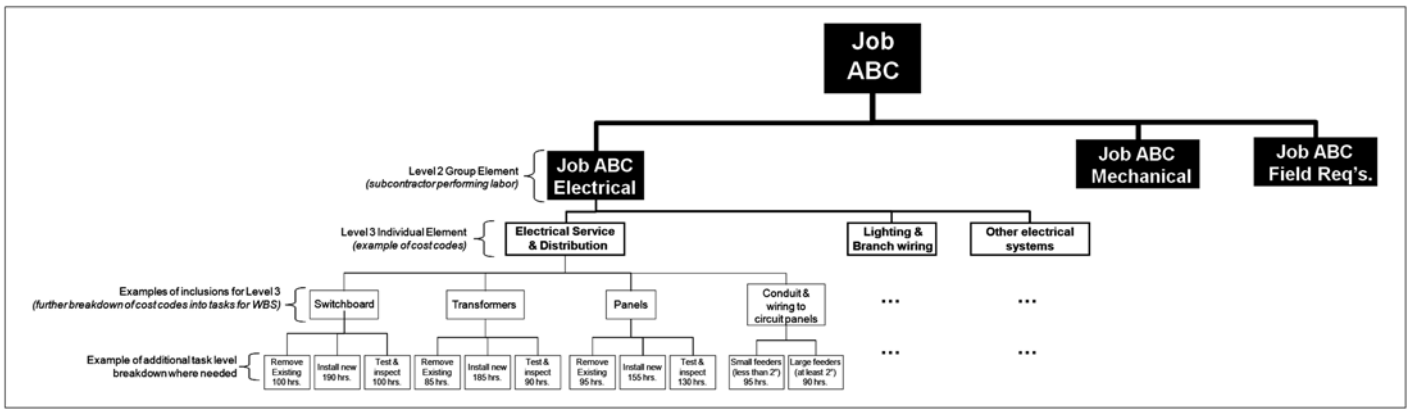

FIG. 3 Partial WBS for Electrical Subcontractor, Based on UNIFORMAT II

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.

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[8] 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).

[8] 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).

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