Automated Productivity Based Schedule Animation (APBSA)

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How to Improve Productivity?

• To improve the production process, two things must happen:
  – The variability of the process must be reduced
    • Prefabrication
  – The level of performance must be raised
    • The rebar crew productivity will decrease because of the common use of large diameter bars required in the design.
Greatest Barriers to Productivity on the Construction Jobsite

• Design: specifications, drawings, documents have to be improved
• Field support for timely responses; have architect/engineer on site with filed competency
• Coordinate Design/Review
• Timely RFIs/RFPs
• Construction/Project management competency
Potential for Productivity Improvement (wrench time)

• Constructability of the design documents with input of major contractors on schedule quality and realism
• Coordination among major contractors
• Pre-project planning
• Communication and teamwork between owners, design professionals, contractors and labor
• Improvement of the construction management process. Considering general contractors instead of construction managers.
Factors that Influence the Direct Work & Unproductive Portion of Typical Work Hour
Work Day Breakdown

- Direct Work: 32%
- Traveling: 13%
- Tools, material, transport: 7%
- Waiting: 29%
- Instructions: 8%
- Personal breaks: 5%
- Early quits, late starts: 6%

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Project Management

• Ineffective management has been cited as the primary cause of poor productivity rather than an unmotivated and unskilled force.
  – Planning
  – Resource supply and control
  – Supply of information and feedback
  – Selection of the right people to control certain functions
Project Management

• Project managers must be capable of managing three interrelated areas of influence to achieve project success:
  – Getting actionable information about process performance
  – Setting policies to effectively control the construction process
  – Minimize buffers that protect against stop-and-go variability
Construction Planning

• Construction planning necessary to manage the project can be categorized in four different areas:
  – Estimate hand-off to project management
  – Job layout and value engineering
  – Procurement planning
  – Job kickoffs (three-day-look-ahead-short-interval scheduling)
    • small
    • well defined
    • measurable pieces reflecting the way the technicians view job progress
    • visible
    • tangible areas such as one room, one area, one wing, one phase, one operation at a time
Constructor Capabilities

• Constructor capabilities those, once adopted, are transferable to raise labor productivity and boost competitiveness:
  – Direct measurement of labor utilization, providing management with key performance indicators for benchmarking and performance-based incentive contract language
  – Top-down “raise-the-bar” continuous improvement strategy to actively innovate and improve the construction work process toward greater value fulfillment
  – Organizational training and learning to create project-wide awareness of working efficiently
Change Order Factors

• Intensity
• Timing in relation to project duration
• Work type
• Type of Impact
• Project phase (Design/Construction)
• On-site management
Scheduled Overtime Effect

- Placing field construction operations on a scheduled overtime reduces labor productivity.
- Where a work schedule of 60 or more hours per week is continued longer than about two months, the cumulative effect of decreased productivity will cause a delay in the completion date beyond that which could have been realized with the same crew size on a 40-hour week.
- Where overtime operations are deemed necessary despite productivity losses (for example, on remote construction projects where bachelor housing is provided at the job site and on maintenance turnarounds) proper management can minimize the inflationary effects. Management actions to be considered include use of an additional shift and periodic shutdown of the work for a Sunday or weekend.
Trends in Real Wages
Labor Productivity Declines

Construction & Non-Farm Labor Productivity Index (1964-2003)

Constant $ of contracts/workhours of hourly workers
Sources: US Dept. of Commerce, Bureau of Labor Statistics

Index

Construction Productivity Index (1964 = 100%)
Non-Farm Productivity Index (1964 = 100%)

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Wage Rate Variances

Labor productivity

"Construction Industry Handbook 2004"
(by Japan Federation of Construction Contractors)
Fig. 7 The trend of relationship between Robot research investment and labor productivity
Pile cap crew Example
• It is estimated that the crew of 5 carpenters and 1 laborer could construct 300 SFCA of forms per day.
• Suppose the crew production for the first pile cap were 100 SFCA per day.
• By the time they complete the 10th cap, their production was 250 SFCA per day.
• Is the estimate of 300 SFCA per day a good estimate?
• Each cap contains 32 SFCA of plywood.
• Equation of the learning curve:
  \[
  N_1 = 100 \times (1)^S = 100 \quad \text{and} \quad N_{10} = 100 \times (10)^S = 250 \text{ then}
  S = \log(2.5) / \log(10) = 0.398 \quad \text{and}
  N_j = 100 \times (J)^{0.398}
  \]
• There is more to building a pile cap form than simply cutting plywood and nailing a box together. They must be placed precisely, braced, and make accommodations for reinforcing steel protrusions. Discussions with several carpenter foremen and superintendents resulted in a limit of about 10 forms of this size per day in a steady state operation.
• This means that a limiting production rate will be 320 SFCA per crew-day.
• After constructing 19 caps, they should be able to meet this production rate.
• Given that 60 pile caps will be constructed, the estimate of 300 SFCA per crew day is not bad.
Learning Curve

average $N = 294$ SFCA/crew day

Pile caps

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• \( Cu = \text{Cost} / \text{Unit} \)
• \( Cd = \text{Cost} / \text{Man-Hour} \)
• \( N = \text{Unit} / \text{Man-Hour} = Cd / Cu \)
• \( C = Cu \times Q = Cd/N \times Q = Cd \times Q/N = Cd \times T \)

\( T = Q/N \)
\( Cu = Cd/N \)
Methods to Quantify Labor Productivity

- Measured Mile Analysis. This method is best used when a project has a clearly defined un-impacted portion, versus an impacted portion, of similar work.
- Industry Studies:
  - Mechanical Contractors Association of America (MCAA) cost manual
  - Construction Industry Institute studies
  - U.S. Army Corps of Engineers Modification Impact Guide
  - The Business Roundtables Measuring Productivity in Construction
  - The Associated General Contractors of America’s National Joint Guidelines
  - The National Electrical Contractors Association’s Manual for Labor Units,
  - Electronics Industry Cost Estimating Data Booklet
  - The Means Estimating Guide
  - Charles’ Leonard’s thesis on the effects of change orders on productivity
  - Richardson’s...
Methods to Predict Labor Productivity

• Heuristics (Historical Data): Portas (1996) found that a contractor’s estimate versus actual labor productivity has an accuracy of plus or minus 15% approximately 40% of the time for concrete wall formwork, and inaccuracies of 50% or 100% are possible
• Expert Systems
• Statistical Analysis
• Regression Analysis
• Neural Networks
• Cycle Time Analysis
• Queuing Theory
• Simulation
• Fuzzy Set Theory provides a suitable approach for solving this problem since it was developed specifically to deal with uncertainties in nature (Zadeh 1965)
Selection of Tasks to be Studied

- Technological intensity of a task (The ratio of equipment to labor cost per unit output)
- Complexity
- Skill level required
- Planning required
  - Labor Driven Activities
  - Equipment Driven Activities
- Interaction with other tasks
Difficulties

• Lack of suitable data for studying long term productivity trends in the US construction industry
• Cost codes should be only high level company cost codes that define the activities performed
• Labor’s perspective
• Comparing the productivity trends
  – Direct work rate
  – Support time (transporting materials and tools, getting instructions)
  – Idle time (waiting or taking a break)
A front-end loader is loading crushed stone into a fleet of dump trucks. The loader has a 5 cy bucket and the capacity of the dump trucks is 20 cy. It takes a loader 5 minutes to load a truck. The trucks can make one round trip to the project site in 50 minutes. There are 10 trucks in the fleet. At the beginning of the day, the loader services 10 trucks in 50 minutes and is idle for 6 minutes until the first truck returns. It loads that truck in 5 minutes and is idle for 1 minute until the second truck returns. This process is a deterministic process that will continue for the remainder of the day with a production as shown in the below Figure.

The dashed line represents the maximum possible production (loader governing). The solid line represents the production limited by the haul units.
BIM Application
Fully Integrated and Automated Project Processes
Automated Productivity Based Schedule Animation Processes

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Database Platform: MS SQL Server
### Productivity Analysis Algorithm

#### Variables

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<th>Factor</th>
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Productivity Ratio: 41

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